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THIS·BOOK·BELONGS·TO

B. F. TUCKER

AMERICA'S ANSWER

to the Russian Challenge

The House Cleaning

This poster, seen everywhere throughout Russia, calls on the citizens of the Soviet Republic to burn up the memory of the Czarist soldiers, the priests, the capitalists, and the Czar's retinue, and in its place to build power plants and industries for the Five-Year Plan.

AMERICA'S ANSWER

to the Russian Challenge

In which electric power,
as a common denominator, is requisitioned to throw light
on the Russian enigma and the challenge it
presents to Western Civilization

BY

ROBERT SIBLEY, B.S., E.E.
United States Delegate
Second World Power Conference
Berlin, 1930

The FARALLON PRESS
occidentis ultimi

58 Sutter Street
San Francisco, California

First Printing

Number 494

Autograph Robert H. Sibley

PRINTED IN THE
UNITED STATES OF AMERICA

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PREFACE

Russia—there would seem now to be no doubt about it—constitutes one of the most serious problems, if not the most serious problem, confronting the civilized world today. We are strangely baffled by it for the reason, chiefly, that whenever we try faithfully to face the issue we find we have no criterion by means of which to form a judgment. The world is turned upside down where Soviet Russia is concerned. The fundamentals of our own superstructure are no longer found there. Russia not only refuses any longer to accept our hypotheses, she has abolished our axioms. When we seek to establish the most elemental common ground, to secure an admission, even for argument's sake, that twice two is four, we are confronted by the retort that no such admission is made.

As a consequence we are tempted to "give up," but quickly find that we cannot. The issues at stake are too gigantic. And so we set about doing what the human mind always does in such circumstances, we set about collecting facts. In other words, we adopt the empirical method of approach.

It is admittedly a dangerous method, revealing at every turn "the gins and snares and pitfalls" of circumstantial evidence. Its conclusions always depend on what we are looking for. The man who burns down his house in order to illuminate his garden may get a more radiant lighting effect than the man who strings some electric lights among the trees, but the method of

the one is a disorderly and disastrous method; the method of the other, an orderly and constructive one, holding out unlimited possibilities of future development.

So it has seemed to me that in our method of approach to the Russian problem and in forming our estimates of whether or not she can "succeed," we have paid far too much attention to the things she has done and is doing and far too little to her ways and means of doing them.

It is, however, impossible to judge fairly of ways and means until we have discovered a criterion wherewith to do it. Such a criterion or "yardstick" may, I think, be found, strange as at first it may seem, in electrical development.

"Communism," Lenin has declared, "is Sovietism plus electrification." Two of these factors we know; therefore, if this statement of Lenin's is true, and it seems to be true, it must be possible to deduce the third. In order, however, to deduce the third, it is necessary to see the first two together, and the only place where the first two are operating together is in Russia. Hence my journey to Russia, and my sojourning there, and this book.

Broadly speaking, I accept Lenin's doctrine. But if Sovietism plus electrification means Communism, the inference is almost inevitable that Individualism, that is, individual effort and the fullest scope for individual effort, plus electrification, means *Americanism.*

The one, therefore, is set over against the other, Sovietism against Americanism, Collectivism against Individualism,

with electricity as the common denominator. That is the Challenge. My purpose in writing this book is to attempt an appraisal of this challenge, a judgment as to its importance not only to America but to the world as a whole.

As to the book itself, I would greatly desire to say this: It seeks to malign no person or group of persons. It seeks solely to establish right thinking where, in the opinion of the author, a wrong basic principle appears to be urging itself for possible adoption as world thinking.

To my Soviet friends of Russia whom I met at the World Power Conference, to those others who acted as guides for my wanderings in Leningrad and Moscow, or whom I casually met and by chance conversed with in my travels down from Moscow toward the Black Sea and westward again to Kharkov and then to Kiev, I wish to express my deep appreciation for the thousand courtesies extended to me. I was a stranger in their land and never once was I made to feel undue inconvenience or to suffer discourtesy.

I offer the discussion set forth in the succeeding pages as conclusions of nearly forty years of active thinking on my part in matters of economic significance, and if this book, through its "scheme" of requisitioning electric power as a common denominator, aids in any way in assessing values that are today perplexing the entire world, it will have served its purpose many fold.

ROBERT SIBLEY.

Berkeley, California,
May, 1931.

Dedication

Whatever is good or helpful within these pages is affectionately dedicated to Harris J. Ryan, professor of electrical engineering in the high voltage laboratories of Stanford University, and Dexter S. Kimball, dean of engineering, Cornell University.

PART I

The World Race for Electric Power Supremacy

AMERICA'S ANSWER

to the Russian Challenge

CHAPTER I

WHITHER?

"RIGHT THERE," said a voice in my left ear, "is the place where I got my first job."

The voice was that of Herbert Hoover, then Secretary of Commerce, later to become President of the United States of America. We were fellow travelers on the Overland Limited from San Francisco bound for Chicago. The train had paused for a moment just before entering the snowshed in the high Sierras in California to give the passengers an opportunity to get out and view the gorgeous scenery afforded by the vast wooded reaches of the American River Canyon spread out below for many miles to the south. Mr. Hoover had been studying the distant southern walls of the canyon and had fixed the terrestrial telescope through which he was peering upon a dilapidated stamp mill in the gray distance. A third of a century before it had evidently been a thriving gold-mining venture, sufficiently thriving at least to give the young Hoover employment as an apprentice mining engineer just out of Stanford University.

The incident, it seems to me, is a forceful illustration of American life and what her conception of "individualism" does for the individual. Here was a man who as an orphan boy had earned his way through college, had distinguished himself later as a great mining engineer and economic leader, and was destined soon to occupy the highest public office within the power of the people to confer upon him. Such an incident bears eloquent testimony in support of the industrial ideals of western civilization and the product of such ideals in human accomplishment. These ideals are closely interwoven with preserving the vital initiative and enterprise of the individual on the one hand, and on the other hand with offering equal opportunity for all.

The theme of this book is to be World Power; the moral of it, the World Power Trend.

Mankind in the early dawn of history began his struggle as tribe against tribe, and then as nation against nation, until the age of Great Monarchs was reached some time during the middle of the Eighteenth Century. At that period we see seated in the highest positions of authority outstanding figures such as Maria Theresa of Austria, Catherine the Great of Russia, Frederick the Great of Prussia, and Louis the Sixteenth of France. This system of Great Monarchs was definitely challenged by social and political upheavals beginning in France in 1783.

Next came the industrial revolution brought on largely by the advent of the steam engine and the invention of tools that caused the transfer of skill and thought from the worker to the

tool itself. Today this same revolution, still in progress and ever accelerated, is vastly extending its activities. The discoveries of Faraday and Henry in their research of 1830 which made possible a utilization of power by means of the method electrical are sweeping civilization on to undreamed possibilities in harnessing the forces of nature for the service of man and in making this energy available at the place most convenient for the work to be accomplished.

Forceful instances will be cited as we progress in our discussion to show this state of affairs today.

Next we shall show how this intensive industrialization has changed the entire struggle of the human race from one of tribe against tribe and nation against nation to that of class against class within nations themselves. Then will follow a discussion of how this class struggle is being met in America, in Germany, and in Russia.

The concluding discussion will be devoted to a description of how the Russian Soviet Republics with their vast population of 150,000,000, occupying a territory one-sixth of the globe, comprising an agricultural area one-third the cultivable area of the world, are today challenging America for world supremacy. By closer analysis we shall endeavor to establish an answer to the question as to whether victory in this race for industrial supremacy—seemingly based on the acquisition of a cheap and economic power supply—will more likely rest with that nation which imbues its citizens with the finest and highest type of "individualism," or the nation whose energies are

dedicated solely to so-called "collectivism" in its method of approach to this problem.

In other words, can civilization really go forward in unlocking the hidden laws of science and in putting these laws to work in the service of man if the great driving power of individual initiative and equal opportunity are eliminated and man relegated to a position similar to that of a cog in the machine which he serves?

CHAPTER II

GERMANY

In June, 1924, the British government officially welcomed to London the first World Power Conference, called together, broadly speaking, to take an inventory of the world power resources. It was the first time in history such a project had been undertaken.

The Prince of Wales, who opened the conference, stated that it was a great source of gratification to him to see that the nations of the world had at last gathered together in a spirit of coöperation through economic measures to bring about the peace of the world, rather than through the time-worn political channels which had proved such a woeful failure.

In brief he said: "You can now explore many countries which have hitherto been veiled in mystery, and assess at their true value the possibilities of an immense industrial development in many of them; you may from this material erect the structure which will go beyond the confines of one country, or group of countries, and include all those parts of the world where man can hope to prosper. International coöperation may emerge from the realm of the ideal into the realm of practical utilization as the result of your deliberations, and I sincerely trust that full success will attend them."

The first World Power Conference was so successful that the year 1930 saw the second World Power Conference, called by

the German government, to meet in Berlin June 15–25, 1930. This later conference brought together a talented and distinguished assemblage of authorities on the engineering, economic, and political life of the world.

Its opening session was called to order by the Chancellor of the German Republic, Herr von Bruening, in the Reichstag building in Berlin. Its papers and discussions were participated in by such men as Professor Albert Einstein, internationally known for his presentation of the theory of relativity; Arthur Eddington, fellow of the Royal Society, and one of the outstanding astronomers of the day; Signor Marconi, pioneer developer of transoceanic radio communication; Thomas A. Edison, world-famous inventor; and Charles A. Parsons, the inventor of the steam turbine.

While it is no part of my purpose to enter at length into the proceedings of the conference, it is pertinent to note in passing how successfully some of the great leaders in scientific attainment aroused the interest of the audience by describing what they saw just over and beyond the field of present accomplishment. There was a curious feeling of expectancy, for instance, in the great conference room when Sir Arthur Eddington dwelt upon the immeasurable possibilities which lay in the "tapping of subatomic energy."

"There is enough energy in a drop of water," Eddington declared, "to furnish 200 horsepower for a year. We build a great generating station of say 100,000 kilowatts capacity and surround it with wharves and sidings where load after load of fuel

is brought to feed the monster. My vision is that some day these fuel arrangements will no longer be needed; instead of pampering the appetite of our engine with delicacies like coal or oil, we shall induce it to work on a plain diet of subatomic energy. If that day ever arrives, the barges, the trucks, the cranes will disappear, and the year's supply of fuel for the station will be carried in a teacup, namely, 30 grams of water—or of anything else that is handy."

Professor Einstein, in speaking of his most recent pronouncements wherein the laws of gravitation and electricity are combined in one equation, carried thinking up from the material into the metaphysical when he said: "Taken together, we can say symbolically: Space, brought to light by the material object and raised to a scientific reality by Newton, in the last few decades, has swallowed up ether and time and is about to swallow up the field and the corpuscular theory as well, so that it will remain as the only theory representing reality."

English, French, and German were declared the official languages, and an ingenious new invention enabled each participant, by means of a specially constructed headgear, to hear translations of the speaker's thought in any one of these languages. This was accomplished by expert translators, stationed in pits immediately beneath the speaker, who whispered into microphones the translation as the speech progressed. Thus each auditor followed the speaker sentence by sentence in the language of his choice.

The keynote of the conference was the rôle played by electricity as a unifying factor in world affairs. The delegates from Soviet Russia, for instance, boldly stated that the success of the Soviet Five-Year Plan is so dependent upon the development of Russia's electrical power resources—coal, gas, oil, and water—that Lenin had fearlessly adopted the slogan, "Communism is Sovietism plus electrification."

Its four thousand participants from forty-five countries, diverse as they were in all other respects, united in bringing to the gathering one common vision on the subject of electricity and its destined place in the progress of civilization.

From Canada came reports of increased agricultural use of electric power; from Japan, world leader in the production of raw silk, an account of the process of electrically stimulating and thereby increasing the productibility of 320,000 tons of silkworm cocoons; from Vienna, the story of successfully heating hotbeds for early plant propagation, and the lighting of poultry yards to increase the working hours of the hen. From Greece, Italy, Scandinavia, from Austria, from America, came contributions to the story of industrial progress through cleverly devised use of electric power.

In short, there was spread before the conference a panorama of world achievement made possible solely through the substitution of this, as man reckons time, new force in the world, this force that has raised the human being from competition with the beast of burden and given him, instead, dominion.

Electric Power Development in Germany

Since the World War Germany has completely rehabilitated her industries. Particularly has she striven to develop her great water power resources. Here is the greatest of her accomplishments, the Walchensee Power Plant in Bavaria, having an installed capacity of 168,000 horsepower. Note the substantial massive type of structure, typically German, built to outlast the Pyramids.

[Page 13.]

The Second World Power Conference in Session

The Second World Power Conference, held in Berlin June 15–25, 1930, brought together 4000 engineers from forty-seven different countries. Note the head-gear worn by many in the audience. This remarkable new electrical invention enabled anyone in the audience to hear the speaker in any one of the three official languages—French, German, or English. The picture shows a session of Section 2 devoted to "Electricity in Arts and Crafts." [Page 7.]

The Brandenburg Gate

The famous Brandenburg Gate was in evidence at all times to delegates of the World Power Conference, for it was necessary to pass through the gate in order to enter the Tiergarten where the sessions of the conference were held. [Page 16.]

It was shown that a direct relationship exists between the per capita use of electricity and the standard of living; but most significant of all, perhaps, was the hope held for world unification through world use of electric energy.

A United States of Europe as a political ideal may be a nebulous hope, but as a power-producing and distributing federation it is a feasible possibility. Development of power resources in various parts of Europe has been retarded to some extent by the size of individual nations, and the development of power utilization in other parts has been retarded by a lack of resources. It is now proposed that the nations of Europe, from Norway in the north to Greece in the south, and from Spain on the west to Russia on the east, be linked together by a network of power lines that will carry light and heat from the most economical generating centers to all consuming centers wherever and whenever needed.

The advantages of such an interconnecting distribution system should be sufficiently obvious to overcome the provincialism of even the politicians. On the one hand is the Danube with its great potentialities for power production during the winter months of heavy rain without prohibitively expensive storage facilities. With the construction of additional power plants such as that now in process of building at the Iron Gate, the Danube is capable of supplying cheap power during winter months to districts at some distance. On the other hand there is the Alpine region which reaches its peak potentialities as a power-producing center with the melting of snows in summer.

By connecting the Danube area with the Alpine region a fairly regular power supply could be obtained without the expense of water storage, at least for many, many years.

A similar complementary program could be developed between the summer potential of the Alps and the winter potential of the relatively low mountains of Central Europe which furnish a substantially greater run-off of water during the winter months.

In addition to these sources of power, an interconnecting transmission system would make available others that either have not been developed at all or have not been developed to their full capacity because of the limited nature of local needs and the distance to larger centers of consumption. The development of the Danube has also been influenced by this situation. But more particularly there are the water power resources of the Dalmatian Coast, from which it is estimated that a million kilowatts can be obtained; and the mountains of Norway, which offer a very cheap source of power with a five-million kilowatt potentiality, but which have been neglected for other than local industrial needs because of their isolation. Whatever holds for water power also holds for thermic energy sources. With properly developed transmission facilities the Galician and Roumanian oil deposits and the Russian coal strata would be available as reserve sources of electric power.

Aside from the seasonal compensation of geographically and climatically varied power sources, the advantages of an international coöperative program for the distribution of electric power

in Europe are still sufficient to justify consideration. One of the economic wastes of large power systems supplying purely local needs arises from the variation in load during the day. A plant large enough to supply peak needs during a day is not working to full capacity during slack or "valley periods" during the rest of the day. By extending distribution lines beyond the boundaries of one time area, power plants can continue to run at full capacity during "valley periods," supplying the peak needs of other centers in different time zones. To appreciate the significance of the time factor in power production one needs only to realize that when darkness is beginning in Moscow there is still an hour of daylight on the Don in Bucharest, that there is an hour and one-half time difference between Vienna and Moscow, that there is a time difference of three hours and ten minutes between Moscow and Lisbon, and one hour between Warsaw and Berlin or Berlin and Paris. Excessive calls for power during the day come at meal times, and by shifting power from a number of points to one time zone after another, the load can be more economically divided. The same problem of peaks and "valley periods" arises in connection with electrified railroads. Cheap and accessible power sources will make possible, as they already have in Switzerland, even distribution.

As the grip of electricity strengthens it draws humanity more closely together, for the sources from which it comes are not found everywhere, and *once developed, power cannot be hoarded but must be distributed*. Just as the people of all nations and races have learned to live together in greater

amity under the democratic ideals of the American republic, so will they learn to think and act together regardless of political boundaries under the unifying influence of electric power. This phase of the European problem will be discussed more fully in Chapter III. To return to the conference—

The Germans were exceedingly anxious to exhibit their recent industrial accomplishments as evidence of Germany's progress under the republic. Particularly were they interested in having the American engineers return to their native land with a good impression. This they succeeded in doing by the very high quality of what they had to display. First they brought forth the venerable and famous Professor Albert Einstein, who, in simple, clear words, gave the reason for a new metaphysical concept in order to represent clearly phenomena of gravitation and electromagnetics in one formula.[1]

We were taken to inspect huge engineering accomplishments, the great Braun Coal Power plants in the vicinity of Berlin where monster machinery of a scale not known elsewhere in the world is at work gouging up fuel and burning it for generation of electric power; the mammoth Ruth steam accumulators in Charlottenburg, unique in design, used to supplement steam power generation for the handling of peak-load conditions in supplying power for the city of Berlin; and, finally, the Benson steam boilers at the famous Siemens plant,

[1] A brief summary of Professor Einstein's conclusions has already been given, and in Appendix V the reader may find a complete translation of his interesting and fascinating pronouncements.

operating at a pressure of 3500 pounds per square inch, were shown in various phases of performance.

Nor were the leaders of German political life overlooked. Teas were given in our honor at the homes of Chancellor Bruening and Foreign Secretary Curtius, while telegrams and letters of felicitations from President von Hindenburg made us feel that their hospitality was real and sincere.

But the greatest "adventure" of all came when the giant Graf Zeppelin was ordered to Berlin from its southern hangar at Friedrichshafen, and a group of us were invited to make a twelve-hour journey with her famous officers.

In our intensive study of economic and industrial Germany, during the discussions of the World Power Conference, and, after the closing of its sessions, during our observations from the Graf Zeppelin as it sailed over mountain fastnesses, river-drained valleys, and great industrial cities, we were forced to the conclusion that electric power development in Germany has taken place in no mean way. It is a unifying force that is observable everywhere in Germany. Not only has Germany developed her water power by standard methods such as are illustrated by the massive Walchensee plant in Bavaria, an installation capable of 168,000 horsepower, but they have carried on studies, ever since the war, of water storage as a means of meeting the peak-load demands on their electric light and power stations. Such water storage systems involve the use of cheap and otherwise unsalable electricity, usually at night, to pump water from a lower to a higher level. Then when the

demand for power is greatest, this stored water is released and, in flowing back, drives water wheels attached to dynamos and thus generates electricity. While this appears very much like lifting one's self by one's boot straps, the Germans apparently have found a way to do it. Today there are in operation or under construction in Germany pumped-water storage plants with an aggregate rating of 600,000 kilowatts.

Some of these systems, however, would not be in operation were it not for the fact that they were built with cheap labor. The back flow of the army, for example, supplied labor in abundance, and it became imperative to divert this tremendous amount of human energy into useful channels or face a serious social upheaval. Some cities, therefore, erected water storage reservoirs to relieve unemployment. The two largest pumped-water storage stations in the world are the Niederwartha, near Dresden, and the Herdecke in the Ruhr. The first is equipped with four centrifugal pumps having an aggregate rating of 180,000 horsepower, and the latter possesses three pumps with an aggregate rating of 110,000 horsepower.

Another development under way in the Southern Black Forest of Baden will store sufficient water to produce 210,000 kilowatt hours of electrical energy annually, and the Prussian Electric Company is erecting a water storage station at Bringhausen, on the Eder River, capable of delivering half a million kilowatt hours of electricity. Four 30,000 horsepower pumps will lift water from the Eder River to a storage basin 985 feet above it.

The Zschoppau dam in Saxony has a storage capacity of 35 million gallons of water, and is located at a height four hundred feet above the water turbines in the power house. The reservoir is filled during the night and on holidays by means of pumps which draw their power from low-pressure hydraulic stations without storage facilities. The water which would otherwise flow idly through these power plants represents when stored in the Zschoppau reservoir, 30,000 kilowatt hours of electricity which is available at any time for peak loads or emergency use.

Formerly when direct current was widely used, electric storage batteries were employed for peak loads. However, alternating current cannot be stored in batteries, and since alternating current is now used almost universally throughout the world in long-distance transmission of power, some other means must be employed in caring for peak loads. The Germans have turned to "water storage batteries." In California, where peak load conditions must be met, the installation of huge steam generating plants has taken place, located usually near the great centers of distribution. These power plants formerly used crude oil as fuel, but at present natural gas is used almost universally. A recent invention using mercury as the driving fluid instead of steam promises to introduce startling new economies in electric power generation during the decade immediately ahead.

Two incidents which occurred during the sessions of the conference will serve to show how genuine is the break with the past

which Germany has already achieved. In order to arrive at the conference hall it was necessary for us to pass through the well-known Brandenburg Gate. Famous in the annals of the history of this gate is the beautiful piece of equestrian statuary which surmounts it. In the early part of the nineteenth century Napoleon carried this sculptural crown away to Paris, and then some sixty years later, following the War of 1870, it was brought back to Berlin from Paris by the Germans.

The history of the gate, and especially of this equestrian statue, so greatly gratified the pride of the late Kaiser that he forbade anyone's going through the center entrance of the Brandenburg Gate save himself. The Brandenburg Gate was, therefore, in its way a veritable symbol of majesty.

On a particular day, being somewhat out of our way and realizing that we must pass through the Brandenburg Gate in order to reach the conference hall, we inquired in rather faulty German of an elderly citizen coming down the road, *"Wo ist der Brandenburger thor?"* What we should have said was, *"Wo ist* DAS *Brandenburger thor?"* ("Where is the Brandenburg Gate?") But what we actually said was, "Where is the Brandenburg fool?" Our friend quickly responded, "In Doorn." Here, in a word, is summed up the German attitude toward the past.

On another occasion, immediately following the conference some of us made an official tour down through Bavaria and other places where hydroelectric development was in progress. In passing through Munich, the representatives of seventeen

different countries placed a wreath upon the tomb of the "Unknown Soldier." This tomb of the "Unknown Soldier" is unusually precious to citizens of Munich in view of the fact that there is carved upon the outer wall housing the tomb the names of thirteen thousand citizens of Munich who lost their lives in the World War.

Along with the wreath and flags of the different nations represented, we laid a note addressed to the Unknown Soldier:

"To the Unknown Soldier of Munich: May the lesson of self-sacrifice you have taught us lead us into a fuller understanding of the principles of international coöperation, and forever free us from the enthraldom of war with its necessity to kill, to maim, and to destroy, in order to forward the common destiny of the peoples of the world."

While we were having our luncheon in a typical German wood twenty-four hours later, the Burgomaster of Munich appeared. He was a man of powerful physique, bearing a facial scar on his cheek, the result most probably of student sword play at Heidelberg or some other German university. The Burgomaster delivered to us an official message from the citizens of Munich. He said that he wished to express to the countries represented sincere appreciation of what our group had done for their Unknown Soldier, and to say that his fellow citizens were in full and lasting accord with the sentiments that had been expressed. The break with the past is complete.

It should be said of the German people, and to their credit, that wherever we had occasion to talk with men of affairs, par-

ticularly those having to do with industrial and engineering matters, we heard this same sentiment, namely, that there must be no more war.

Germany, indeed, seems to have her face set definitely toward peace. Every available square foot of her vast area is under intensive cultivation. We found the German people themselves well disciplined mentally and physically and active in industrial research of all kinds. They are holding themselves well in hand; no luxurious living is visible, and yet from a hygienic viewpoint their athletic vigor, furthered by hiking, canoeing, skiing, and outdoor sports of all kinds, has given both men and women unexcelled physiques which fit them to carry forward the nation's work with the greatest possible efficiency and personal satisfaction.

The words of Doctor Oskar von Miller, president of the second World Power Conference and founder of the famous German Engineering Museum at Munich, in closing the Berlin-to-San Francisco radio broadcast on the night of the banquet to the visiting delegates, in Berlin, typify the high aspirations of modern Germany: "The valued friendships which bind me with men of different nations, especially with Americans, is not due to business relations but to our common endeavor to promote science and technology and to make knowledge available to the greatest number of people."

CHAPTER III

EUROPEAN POWER DEVELOPMENT

BEFORE DISCUSSING in more detail the vast European power interconnection proposed at the conference and already referred to in the previous chapters, let us get a bird's-eye view of the leading countries of Western Europe in the matter of power development.

First of all, then, in regard to Great Britain, any careful review of the situation reveals the fact that, although Great Britain next to Germany and France outranks all other nations of Europe in electric power consumption, undue conservatism is retarding progress to some extent. There is at present a movement under way known as the "grid system" which will bring about interconnected power supply, but I would say that, on the whole, England today is trailing Germany in power development.

France, on the other hand, at the present time is enjoying a joy ride to prosperity. Millions of dollars are being poured into Paris from American travel, and the French peasants and thrifty city dwellers are putting aside great quantities of this money brought to them from across the seas. They are enjoying a period of prosperity seldom experienced in their republic. Germany and France are about on a par in total electric power consumption, and are today the unquestioned leaders of Europe

in broad uses of electricity. France is devoting unusual energy in the electrification of her railways.

Italy seems to be forward-looking in the matter of engineering and industrial progress. She has developed her water power in the Italian Alps, and certain of her volcanoes have been harnessed and the gases from them passed through tubes, thereby evaporating water into steam, which in turn causes the generation of steam electric power to the extent of many thousands of kilowatt hours.

The precipitous slopes along the coast of Norway have been utilized for the laying of pipes to bring the water of nearby mountain lakes down to sea level, making possible cheap power for the development of the electrochemic industry. Hence, Norway has become the great world center in the development of electrochemic products.

The Swiss, too, have taken advantage of their water power resources to a remarkable extent. Precipitous pipe lines run down the almost vertical slope of the Alps from the melting snows above to the valleys below, through which water at high pressure is used to develop hydroelectric power for the operating of the Swiss railways. And so today we find the Swiss in electrified railway development leading the world. Within a year or two electrification will have been completed, and all the federal railways will be operated entirely by electricity.

Austria is active in doing what she can with her natural resources, but today she is laboring under the severe handicap imposed upon her by the reduction of her territory.

Czechoslovakia, to the north, has advanced to an extended industrial progress and feels the vigor of a new youth. Poland, however, billeted between Russia, on the one hand, and Germany, on the other, lives under constant terror that the Germans are arming, through their civilian guard system, and will some day sweep down upon her to destroy her independence; or that the Russians to the east, with their vast Soviet Army, are waiting to attack her from that direction if Germany does not act first. Poland, as a consequence, in the matter of electrical development is largely at a standstill.

And the little countries up along the Baltic—Lithuania, Latvia, and Esthonia—each has a development under way that is interesting and significant, especially when considered in relation to the Russian situation, but is of little economic importance from the point of view of the world as a whole. Finland, too, with its great city of Helsingfors seems busy and active.

Electric power development, on continents other than Europe and North America, has not taken place on any extensive scale, with the exception, however, of the Island Kingdom of Japan which ranks well up with Italy and Great Britain in this regard. In 1929, Japan's total consumption of electrical energy was in excess of 8000 million kilowatt hours, twice as much as either Soviet Russia or Sweden.

Anyone who has visited Japan and her island possessions in recent years must carry vividly in mind the part electricity plays in her artistic and industrial life. Her power development on

the island of Formosa, where 90 per cent of the world's supply of camphor is obtained, is impressive.

With this brief general survey of the situation as a whole, we are in a better position to consider the gigantic European superpower system which was one of the most interesting proposals at the World Power Conference. The system is based on economic grounds and envisages linking the water powers of Norway, Sweden, France, Switzerland, Spain, Italy, Austria, and Jugoslavia with the coal resources of France, Germany, Poland, and Ukraine, the lignite resources of Germany and Czechoslovakia and the oil resources of Roumania and Ukraine.

The network will be like a huge trough of electricity fed from various power systems, and from which industries and towns will take all or part of their electric supply. There is little likelihood, however, of any electricity that is generated in Norway, for example, being used in Spain, or vice versa. Under normal circumstances it is expected that most of the electricity will be consumed in the country of its origin. Any excessive demand which France might make on the system at Paris would in all probability be met either from steam-driven power stations at Calais or from hydroelectric stations near Lyons. It is pointed out that there are economic limits to the transmission of electricity even at the high pressures and in the large quantities proposed.

The idea behind the Pan-Europe superpower network is to conserve what would otherwise go to waste and to make pos-


NORWAY
SCOT. LAND
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IRELAND
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Dublin
Liverpool
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Southampton
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NETHER-LANDS
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BEL-GIUM
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Koblenz
Treves
Paris
Reims
Nurnberg
Munchen
Nevers
Bern
Zurich
FRANCE
Geneve
SWITZERLAND
Innsbruck
Lyon
Trent
Milan
Verona
Pavia
Avignon
Genoa
Beziers
ITALY
SPAIN
PORTUGAL
Zaragoza
Lisbon
Talavera
Madrid
Barcelona
Corsica
Balearic Islands
Rome
Sardinia
ATLANTIC OCEAN
MEDITERRANEAN SEA
Sicily
Power Sources to be Developed
Water Power
Thermal Power (coal)
Thermal Power (lignite)
Thermal Power (oil)

The Proposed European Superpower System

European engineers proposed at the Second World Power Conference a vast interconnection of power. About six thousand miles of high tension line will be required, and the transmission pressure is to be 380,000 volts—the highest thus far attempted in long-distance transmission of power. [Page 22.]

sible the production of electricity and the utilization of natural resources in districts where, without such a network to absorb and distribute the power, complete electrical development would be uneconomical.

In principle, only such power will be imported from other countries as cannot be had at home or is available there only at a higher price. Among the advantages favoring the superpower network are the compactness of Europe as compared with the other continents of the world and the fact that the industrial sections of Germany, France, and Italy are within easy transmission distance from Switzerland. Great Britain is now engaged in completing a superpower network of its own, and the greater part of Soviet Russia is said to be too far removed from the rest of Europe to be included in the network.

Five trunk lines are contemplated—three running north and south, and two, east and west, the latter interconnecting the former. About six thousand miles of high tension line will be required, and the transmission pressure is to be from 380,000 to 400,000 volts, or double that now in commercial use in this country. Naturally, the network will embrace all the industrial districts and large towns of continental Europe, inasmuch as they offer the largest markets for electric power.

The first of the north and south lines will connect the water powers of Norway and Sweden with the central German lignite districts by way of Hamburg and Berlin. Thence it will traverse the water power district of the high Alps, continuing through Brenner Pass to Genoa and possibly to Rome in Italy.

The second line will start from the vicinity of Calais, France, where large steam power stations will have the advantages of cheap coal from England, Northern France, and Belgium, and will run via Paris and Lyons to the water powers in the Rhone district, continuing to Barcelona and to Zaragoza, in Spain, where water power is available, and finally to Lisbon, in Portugal, which is favorably located for European coal. The third line will connect Warsaw, Poland, with the German–Polish coal district and will pass through Czechoslovakia by way of Vienna and the Austrian water power district to Jugoslavia, thus tapping the water powers on the Dalmatian coast and connecting them with the European superpower system.

Of the lines running in an easterly and westerly direction, the first will tap the north–south line extending from Warsaw near the German–Polish coal region, where a connection with the Galician oil area is possible. Continuing, the line will traverse the lower Silesian coal fields to the central German lignite regions near Halle. There it will cross the north–south line from Norway to Italy and will continue through Western Germany via Coblenz, tapping the west Germany hard coal and lignite district. Passing thence via Treves to Paris, the line will interconnect with the Calais–Lisbon line.

The second and longer east-west line will extend across the southern section of Europe. Beginning at Rastov in the Donetz coal regions of Russia, it will run to Alexandria, which is near the Dneiper water-power development (the largest in Europe), and will continue to Odessa on the Black Sea. There a

steam power station using Caucasian oil may be erected. The line will continue through the oil regions of Roumania to Bucharest. From Bucharest a branch line is contemplated which will supply electricity to Bulgaria and Turkey.

The east-west line from Bucharest will pass via Budapest to Vienna, where it will join the third north-south line. This section of the line will traverse the large but yet undeveloped water powers of the Danube at the Iron Gate. Continuing westward from Vienna, the line will tap the developed and undeveloped water powers of the Austrian Alps and pass through the entire Alpine region of Switzerland and France. It will terminate at Lyons, where it will interconnect with the Calais–Lisbon line.

The nucleus of the system is already in operation. Norway, for example, exports power to Denmark, and the transmission of large blocks of power from Norway to Germany via Sweden and Denmark has been under consideration for some time. Switzerland supplies adjacent power systems in Germany, Italy, and France. As a matter of fact, the interconnected Alpine power network spreading over Switzerland, Northern Italy, Austria, Southeastern France, and Southern Germany represents electric power generating facilities aggregating more than 4 million kilowatts and capable of producing 20,000 million kilowatt hours of electricity annually, thus making it one of the greatest power zones in the world. Power ebbs and flows across national borders, and in winter electricity from steam stations in France and Germany is transmitted in

large quantities to the Alpine regions to augment the supply of power during the season when most of the streams are frozen.

Although the problem of interchange of power between the various nations has not yet been definitely settled by the governments concerned, the interchange now taking place is of unquestionable benefit to buyer and seller and is based on mutual understandings. An international agreement relating to the transfer of electrical energy and the development of water-power resources in which a number of countries are interested was reached by the League of Nations on December 9, 1923. Nevertheless the problem is still fraught with political difficulties leading to restrictions. The superpower system outlined, therefore, can only evolve gradually as economic conditions dictate. Its total costs, including regulating and transformer stations but not generating stations, are estimated at $500,000,000.

It is no longer necessary to point out the economic advantages of interconnection of power stations and supply systems within one country. The facts speak for themselves. Further advantages are claimed for international hook-ups because they permit of greater exchange of electric power, better utilization of existing power systems, the development of hitherto untapped sources of power, and the supplying of electricity to the widest territories and the greatest number of people. This makes for economy and better service.

Nature has not distributed her wealth uniformly, and it is proposed to import and export electricity exactly as other com-

modities in international trade, but with the freedom which marks international telephonic and telegraphic communication. Power zones will, of course, be created in those parts of Europe where nature supplies abundant resources of coal, lignite, oil, or water.

Electricity not required in the country of its origin will be transmitted beyond the national boundary, and power will be exchanged between countries which, from the point of view of power resources, are supplementary, as, for instance, Italy and France.

The economic and social advantages of such a development could not well be exaggerated. And yet it must be clear that it is entirely dependent for its consummation not only on economic and social advantage but on international good will and mutual understanding. It is just here that once again *Electric Power* is seen to emerge as the new common denominator among men. The development of physical unity and mental unity always go hand in hand.

Throughout the world today this twin advance is everywhere apparent, and it is now a world advance. Men are everywhere dimly conscious of the advent of a great unifying power in the realm of physics, and, significantly, they find it in line with another great unifying power or principle which they dimly discern in the realm of mind, a principle which they call disarmament or international unity.

Everywhere we discerned the unseen presence of these two great powers and their effects. We saw it in the gathering

together of men of all nations, eager to confer on one question, *Electricity,* in the conference held in Berlin. We saw it in the man by the Brandenburg Gate, cutting free from the old landmarks and glad to see them disappear, and we saw it more clearly than ever, perhaps, later on when, as the recognized representatives of the new day in the realm of physics, we stood and listened to the Burgomaster of Munich—after our visit to the tomb of the Unknown Soldier—listened to him as he endorsed our hope for the coming of the new day in the realm of spirit.

In a word, it seems that Lenin's saying might well read, "Good will plus electricity means World Peace."

CHAPTER IV

THE RUSSIAN FRONTIER AND THE STREETS OF LENINGRAD

At the little frontier border town in Soviet Russia, situated on the railroad between Helsingfors and Leningrad, occurred the first incident of the many hundreds which during the weeks that followed were to build up my education. I would like to describe it in some detail.

We had in our group a number of Russian women, Jews, now American citizens, whose families still lived in Soviet Russia. These Americans were traveling from America to pay their kin in Soviet Russia a visit in an endeavor to find out the true conditions that prevail in their native land. They spoke perfect Russian and so I requested one of them to ask two of the young Soviet soldiers how they liked military service. A young chap about twenty-one years old, fair-haired, and blue-eyed, spoke up.

"I like the service in the Soviet Army," he said, "for two reasons. First, in the days of the Czar when the army was gathered together he would take those from Vladivostok and bring them over to Leningrad, and those from Leningrad and take them over to Vladivostok, so that if he had occasion to fire upon the people generally there would be no hesitancy on the part of the soldiery to shoot down their fellow citizens. But under the Soviet régime the soldier is kept in his own

neighborhood where he has been raised. During his years of military duty he is taught to read and write, and given an elementary education. Before coming into the service I could not read or write, but now I enjoy greatly my reading, and I feel that I owe this to the present military régime."

The soldier, therefore, I learned at once was contented, not only with what he was promised but with what he had. Later on I learned how essential it was to the Soviet plan that this should be the case.

We went on to Leningrad. I only wish that words were adequate to describe my impressions as we went through the streets of this one-time pride of the old Russian Empire, now so quiet, so ominous. Perhaps the feeling that I had when I went through the streets of San Francisco immediately following the great earthquake and fire of 1906 was the nearest approach to what I felt in Leningrad. There was not so great an accumulation of *débris* in the streets of Leningrad as there was in those of San Francisco, but there was the same presentiment that some superhuman power had visited the place, had held it in the hollow of its hand, and threatened it with extinction.

The people in Leningrad walked about silently but in great numbers up and down the sidewalks. A few were in the streets themselves, for there are not many automobiles in Russia, and practically no other conveyances save the street car lines, which are thronged.

Arriving at the Europa Hotel, a hotel which compares well in size with some of the larger hotels in America, we found a

strange condition of things. As we entered the main lobby, the only servant or attendant in sight was an old man. He was dressed in overalls, typifying the worker, and sat in the seat evidently reserved for the hotel manager. He seemed mentally to be of a caliber very inferior to that of a man one might expect to find there. We talked to him through an interpreter, and finally he told us that we could have rooms on the fifth floor. As the elevator was out of order, we were forced to climb the five floors with our hand baggage.

This type of hotel service seemed general throughout Russia. For instance, on another occasion, in the city of Kiev, at the great Continental Hotel the manager fumbled around to find his keys, and then became aware of the fact that the maid had them up on the fourth floor. There being no telephonic communication with the various floors of the hotel, he went out to the center of the court and yelled in Russian up to the maid that the key of a certain room was wanted and would she please throw it down. Such is the service in the most famous hotels in Russian cities. Sometimes the elevators run and sometimes they do not. At this Leningrad hotel we were first conducted to the top floor, where dinner was served. The supply of food is very limited. That furnished us consisted of black bread, lettuce, and meat, together with a simple dessert. No butter.

Since Leningrad is in about the same latitude as Greenland, the "days" in midsummer are almost twenty-four hours long. As a consequence, at eleven or twelve o'clock in the evening we went out in broad daylight upon the streets on sight-seeing

tours. Our party, as a rule, was conducted by an official representative of the In-Tourist, which is the travel service of the Soviet government. We were put under the leadership of one of their capable young women who spoke English fluently. On the first evening, she took us to the great open square where, she informed us, in 1905 the people had asked the Czar and his representatives for work and food, only to be ruthlessly shot down. Then she led us to the public building where Lenin had been concealed just prior to the days of the Revolution in 1917 and from which, at the psychological moment, he had stepped forth, his supporters having already cut the telephone wires, and gained secret control of the army. Within one hour he had overthrown Kerensky and his régime, and, with little bloodshed, had assumed full and effective control of the vast Russian Empire.

Then our guide exuberantly said, "Let us next visit what was formerly the private home of one family but is now the home of *two hundred!*"

Picture, if you will, the most beautiful home you have ever known. Picture a home with marble walls, with exquisite draperies and soft hangings, with celebrated portraits on every hand, with statuary of great beauty on all sides, and even then you probably could not surpass in your imagination the beauty of this home to which our guide led us. Taken over by the Soviet government, as have all other houses of the kind, it is now being used as an "outing place" for the workers. Each industry provides its workers with a two weeks' vacation, and

it is in this and in other like mansions that they sojourn, with expenses paid as a premium for service through the year.

As we went through the various rooms and halls I said to one of our party who spoke Russian, "Ask this group of young girls here what they think of America." One girl—she was about seventeen years old and a textile worker—did most of the answering.

"Well, I don't think much of America," said she. "You exploit the workers in America. But you just wait. We have better working tools than America has. We have a five-year plan which we are going to complete, and when we have completed it, we are going to show capitalistic America that when we do not exploit the worker, we can produce things cheaper and better."

On our way back to the hotel we passed by the Communist University, and here the motor bus was stopped and our young woman guide delivered quite a sermon on the forward-looking ideals of the Soviet in the matter of education.

As she spoke, an old man without shoes and in tatters was observed watching and listening very carefully. Suddenly, as if he could stand it no longer, right in the midst of her eloquent address glorifying the Communist Party he hurled forth some words in Russian. The guide turned on him a withering look of contempt, and I asked one of my Russian friends what he had said. "Something quite true," she replied. "He said, 'She talks that way and yet here we are without shoes.' "

Meanwhile, the old man staggered away, leaving in our minds a deep sense of that grotesque contrast between promise and achievement such as later we were to find is everywhere characteristic of Russia today. "She talks that way and yet here we are without shoes" might well serve as a legend to be written large over the gates of Soviet Russia.

CHAPTER V

SOVIET EDUCATION

THE NEXT DAY we were taken to an educational exhibit illustrating the methods of teaching and the ideals toward which the Soviet educational system is working. Here we saw a building of comfortable proportions, said to be the model exhibit of the school system of Leningrad and its district. In this building there were literally thousands of exhibits, made by the boys and girls as part of their school exercises. We asked for a guide to explain the exhibits to us. We were introduced to a young man in overalls, without necktie, who was evidently some authority in the school system of Leningrad. First, he explained the Russian educational system from a chart that some child had drawn. Education in Soviet Russia, it appears, begins with the child at one year of age. At this early period, the child is taken into the Home of the State and put in charge of a corps of attendants; one to oversee its exercise, one for its proper health, one for its food, one for each phase of its early training. The first division in the Soviet educational system is for children in ages from one to three.

"Does not the child grieve for its mother and miss its home life?" I asked the attendant.

"Oh, no," he replied. "Just the other day one of the mothers came to reclaim her child after he had been with us three years. As she fondled him, the child began to cry. 'Why, what's the

matter? Don't you want mamma?' At which point the child cried the louder and whimpered, 'No, I don't want mamma; I want mammas.'" This incident seemed to me significant and, somehow or other, strangely ominous.

Between the ages of four to seven the child is sent to a kindergarten, where it participates in outdoor life, and in an elementary way learns gardening. From eight to eleven, he is taught the uses of electricity in the home, the preparation of food and the care of the house. Here is the first emphasis put upon the gigantic industrialization ideals that pervade the Russian mind.

From twelve to fifteen years of age, boys and girls are sent, some to the farm, some to vocational enterprises or other practical training centers. All educational effort in Russia must have a vocational or industrial object. Education begins with the practical application and then proceeds to the lesson to be drawn from it. From the ages of sixteen to twenty, those who have been exceptionally proficient in these earlier stages are given a technical and cultural finish in order that they may become teachers.

At the age of twenty, a boy or girl is, theoretically at least, prepared for life as a citizen under the Russian Soviet government.

At one point in our tour through this palace of education, I noticed a number of youngsters following us from exhibit to exhibit. I turned and asked one of our American visitors who spoke Russian to inquire of some of the young girls what they proposed to do in life when their schooling was complete.

Soviet Soldier at the Former Palace of the Czar

Careless in dress and totally indifferent as to personal appearance, an effect no doubt purposely achieved in order to emphasize the attitude of the Soviet Government to the pomp and circumstance of the Czarist Guards who formerly kept watch here. [Page 51.]

Electrical Development in Soviet Russia

The gigantic Five-Year Plan in Soviet Russia calls for the construction of 2,846,000 kilowatts in electric power plants by 1933. An additional 5,300,000 kilowatts of installed capacity is under contemplation for the succeeding ten years. [Page 47.]

Said the interpreter, "What do you girls propose doing in the way of further education, and what do you propose for your life work?"

Immediately spoke up a youngster about fifteen years of age. "Why, even though I'm a girl, I want to be an engineer. Please ask the gentleman with you, who, I understand, is an American engineer, to take me to America in order to teach me how to build things. I will come back and build buildings. Oh, ever so high—higher than any buildings ever known."

Upon asking other similar questions, our interpreter found that one wished to study medicine, while another was preparing for a chemical engineering profession, and so it went.

"Now," I said, "ask them what they think of America."

We found that these youngsters did not think a great deal of America because "Americans were known to exploit the work of the laborer." They did admit, however, that they would like to go to America to see what it was all about, and they all admitted that they liked the silk stockings that American women wore.

Education in Russia seems to lack that spark of enthusiasm which pervades educational life in America—certainly that sense of buoyancy and good humor possessed by the average educator in America is not to be found in Soviet Russia. I am thinking now of the reply of a young Soviet university student to the question as to whether students played football in Russia.

"Russian students," he answered, "are far too serious to play football."

Life is, indeed, too heavy, too drab there. Something is lacking to give education the bubbling vivacity it has in America. The lusty cheers of ten thousand students at football rallies; the rows of eager faces around the crackling fire darting skyward in the center of the diazoma of the Greek Theater in Berkeley on a gorgeous California night, for instance; the breathless silence at the kick-off; the joy of greeting college mates in victory, or the satisfaction in a friendly sympathetic voice in defeat —all these associations keep alive life's enthusiasm and aspirations engendered in the formative years of youth. I wonder what chasms are left vacant in life's enthusiasms in Russia due to their lack.

Next, we were led to a room where many illustrations of a religious nature hung upon the wall, illustrations evidently drawn by young children between the ages of eight and ten years. We wondered what it all meant.

"It means," said our guide, "that in Russian schools we are teaching our pupils not only to be nonreligious but antireligious."

Upon asking reasons for it, he continued, "Because religion teaches passivity, and passivity is the wrong concept of the cosmos. All of this"—pointing to scenes from the crucifixion, paintings and frescoes of the Virgin Mary, familiar to Christian doctrine—"are but myths and fables, from which we wish to free the minds of our children. We want none of these myths in our present-day instruction. If there is to be a religion, let it be Communism."

Thus they are proposing to direct the energies of their 150,-000,000 people to uproot completely religion, that supreme issue over which nations and peoples since time began have gone to war and suffered every conceivable human sacrifice, even to physical torture, to preserve. How different from the German atmosphere in which I had recently been submerged when, two weeks previously, I had attended the Passion Play at Oberammergau.

In the next picture, that of a youth at his study table, poring over some physical experiments, I asked what the child who had designed this poster desired to portray.

"That," said our guide, "is to teach that the sole thing upon which one can rely in life is what he can find from the laws of science to guide and direct him. The basic educational theme that we teach to all of our children in the schools is the fact that *there is no individuality; that collectivism is the thing and the only thing.*"

High on the exhibit wall, in a niche, was a piece of statuary, a figure of a fine looking youth dressed as a soldier, with bayonet fixed, leaning out and protecting a young child studying his books, and below it an inscription, translated for us as follows: "Now let any damned bourgeois harm us!"

From observation of the thousands of exhibits in this exposition, it is evident that the cultural activities of Soviet Russia follow two parallel courses—the "raising of the cultural standard of the population," and the creating of "a new cultural atmosphere opposed to that of capitalism and religion."

In January, 1925, there were, according to Soviet statistics, 87,000 schools of the first grade, with 6,817,000 children; 17,000 coeducational primary schools of the secondary grade, with 2,228,000 pupils. How near this is to the truth or how far from it, there is no way of judging. The Five-Year Plan in Soviet Russia, to be dealt with in succeeding chapters, calls for the stamping out of illiteracy by *1933!* The italics and the exclamation point are perhaps the only possible comments.

CHAPTER VI

PROPAGANDA

In the course of our stay in Leningrad we were invited to witness the first talking picture ever to be exhibited in Soviet Russia. It was a picture, we were told, which had been designed by the General Commissariat to tell the people of Russia what the proposed Five-Year Plan now under way is to accomplish.

I wish I had the language to describe this picture adequately—to reproduce the drive and persuasiveness of its presentation.

We were ushered into a room where were seated perhaps three or four hundred people. There was a moment's silence—then suddenly we were startled by the shriek of a steam siren! On the screen a picture was emerging out of a blur of light and shade. The firmament was being torn apart—the clouds driven back—and we could see Russia, America, Germany, and other countries of the world in process of creation. Then, again, the whistle—and we saw the Russia of the Czarist régime; vodka-drunk people on every hand; dissolute women plying their trade; immorality and corruption enthroned. The whistle blew again—and peasants by the hundreds and thousands were coming in from the fields of the vast agricultural districts of Russia; agricultural districts that contain one-third of all the cultivable land of the world. They were coming from the fields

into the cities, and in their place massive tractors—miles and miles and miles of them—were going out to harvest the crops, to plow the fields, and to perform all the tedious drudgery of agriculture.

No longer needed to till the soil, the peasants were coming to take part in the great industrial life of the cities.

Then again—the whistle! The scene had shifted to the great rivers of Russia, the Vistula, the Dnieper, the Volga, and the Ungara, with their vast waterfalls and power sites in process of development. Great concrete-pouring machines plying their trade; dams being erected; hydraulic intakes installed; great generators put in motion; and the vast, natural power of an empire harnessed for the work of men! Then, once again, the whistle! This time tremendous industries are being evolved. We saw great steel plants with molten iron cast in the forms of electric ranges, automobile equipment, and a thousand utilities for the industrial life of a nation.

The scene shifts as the whistle blows once more, and this time appear people engaged in every conceivable industry, women working in small motor manufacturing plants; men designing and erecting all types of automotive equipment; homes being built; great buildings rising; and all the useful arts put to work in the building of an empire!

Again the whistle—and before our eyes march the vast army of Russia, said to be the largest standing army in the world today, somewhere between 500,000 and a million men under arms. The soldiers do not march with rifles only, but with

bayonets fixed, and they march by in thousands upon thousands, bearing banners with inscriptions similar to the one we had seen in the educational building, "Now let any damned bourgeois harm us!"

For the last time, the whistle! Before us is a giant map of Russia. Again the great rivers and scintillating lights that dart out from the power sites located on them. These scintillating lights shoot from Moscow to Archangel; from Moscow to Leningrad; from Moscow down to the Black Sea or the Dnieper; from Moscow to Vladivostok; and from Vladivostok up to Archangel; until we are looking at one vast, pulsating illumination of a great nation, industrialized; a nation producing its wares for the upbuilding of an empire and designed to overwhelm, in its efficient industrial strength, all other nations in the world today!

A wonderful *picture!* But, somehow, as one emerged from the darkened hall into the gray light of day, it was not this picture, but that of the old man outside the Communist University and what he said that remained uppermost in memory: "She talks that way, yet here we are without shoes."

What sort of propaganda is disseminated to the people of Russia? There is nothing that can reach the people save what filters through the fingers of the Commissariat! The News Topics of the day, flashed upon the screen, after the Five-Year Plan picture had been displayed, is an index. The first picture was that of the Disarmament Conference in London in session. In ironic contrast immediately following it came a naval pa-

rade, showing the vast armaments of the various powers participating in the conference; America, with her great Pacific fleet entering the Golden Gate in San Francisco Bay!

The newspaper *Pravda,* which in English means "Truth," is the official news sheet for the Soviet government. So I asked one of our group to read me a copy of this paper from cover to cover. It was interesting to see how much space was devoted to the Soviet régime and to the "progress in Sovietism" of the world at large. For instance, there was a page telling of a crash on Wall Street, the article going on to say that the break was so severe that the capitalist system in America was on its downward grade and would soon fall. Indeed, *Pravda* would not be surprised if in six months "Soviet America" would take the place of the defunct capitalistic régime.

In another magazine published by the Soviet government, a half-page illustration purported to typify America under capitalism. Here was pictured a lynching that has just taken place in Oklahoma, the charred remains of the victim burning in the fire below a tree from which it had so recently dangled. Then an article describing what was happening in England under Ramsay MacDonald. It mentioned the fact that a number of tanks were being sent down into India to subdue the downtrodden people there. In order to show how capitalistic England treats her subjects, the article was accompanied by an illustration dating from the Indian Mutiny of three-quarters of a century ago! In the course of this rebellion, it will be recalled, the British made a terrible example of certain rebels by tying

them to cannon and then blowing them to pieces. The caption to the reproduced picture reads, "This is the way capitalistic England treats its subjects."

CHAPTER VII

CZARISM AND AMERICA AS SEEN BY THE SOVIET

One of the most interesting "exhibits" of Sovietism in Leningrad is the beautiful palace of Nicholas II, where he and his family were held prisoners before they set out on their fatal journey to Ekaterinburg. At the entrance to the palace was a statue of Lenin and, as if to display a strong contrast between the Czarist and Soviet régimes, the guard at the entrance of the palace no longer was a soldier in resplendent uniform but, instead, a Soviet private, bayonet fixed, with no necktie, wearing a soft collar, lounging informally before his sentry box.

Within the palace we were treated to a veritable torrent of propaganda. Articles were displayed on every side that indicated the cruelty and extravagance of the former Czar and his forbears, and the "treachery of the Czarina." The Czarina, being a German, we were told would get from the Czar secret state information and pass it on to Rasputin, the middle-Asian priest and hypnotist, and he in turn would issue those pronouncements which brought ruin upon Russia.

Here, on the one hand, were the beautiful and exquisite gowns worn by the Czarina at the official affairs of state; there, the uniforms which the Czar wore in the parades and formal ceremonies encumbent upon his office. Here was his pipe, a twelve-inch affair, carelessly lying upon his bureau as he left it. Here again, in the bedroom of the Czarina, was a picture of

ill-fated Marie Antionette, and our guide called attention to how fate had decreed a similar violent death for the Czarina. Here, in effigy, were lackies, guards, and footmen resplendent in their uniforms as in the days of old. In strong contrast were the Ethiopian guards also shown in effigy—those guards so much beloved by the Czarina.

Finally, as an impressive climax, we were ushered into the official reception room where the Czar was accustomed to meet his embassies of state gathered from all parts of the world. "And here," our guide announced, "you will see how our Emperor, the Czar, who was so fond of his yachting that he must have his yacht even in the serious affairs of the empire, has fitted up his official room of state to look like a yacht." Blue coloring on the walls, a hatchway over toward the hall, and other nautical features made it indeed look like a yacht.

"But, see," continued our guide, "that hatchway is not in reality a hatchway, but is a secret passage through which the Czarina could come from her boudoir over into this room of state, and, unobserved, hear what was going on in the discussions, and having learned, would cross back again to her room and carry her information to the traitor, Rasputin."

We investigated, and surely enough there was a secret passageway from the Czarina's room up over the hallway to the simulated hatchway in the room of state where the eavesdropping took place—were our guide to be believed!

After leaving the palace, we had forcefully impressed upon us an example of the campaign that is going on in Soviet Rus-

sia today for the elimination of private business. The Soviet government has not technically ruled out private business, but has made private business so difficult to carry on that it has practically passed out of the picture. Here, however, before us was one of the few remnants of private enterprise, a vendor of ice cream dainties. A little wafer, with a spoonful of ice cream that could in this country be bought for a few cents, was being sold for thirty kopeks, or the equivalent of fifteen cents in our money. We were told that if a member of the Communist party were to buy the same article at a nearby Soviet-owned shop it could be procured for three cents. So high is the tax upon private enterprise, the price we paid was necessary if the vendor was to live.

We next journeyed from Leningrad to Moscow by rail. We all remember the story of how the Czar one day called his greatest engineers together and told them he wanted a railroad built from Leningrad (then St. Petersburg) to Moscow. Of how one engineer advised a certain passageway, circuitous, over the mountains and across rivers. Another an entirely different route, and still a third was sure that it was only possible to build the line by a swing far to the west in order to avoid costly bridges and lengthy tunnels. How then the Czar, in his majestic and imperial power, laid upon the map a ruler and drew a line straight as an arrow between Leningrad and Moscow, and said: "Build it that way."

This is the railroad route from Leningrad to Moscow today. It is a masterpiece of construction. And even though it plows

its way through vast cuts and tunnels, it is a silent tribute to an age that is past, and bears witness to the power and wealth of the Czarist régime.

As we looked out from our car windows at two-thirty o'clock in the morning, we could see the arctic sun already rising and peasants at work in the fields.

Moscow we found not so depressing as Leningrad. However, living costs are excessive. A luncheon at the Metropole Hotel, consisting of a Russian soup, which in itself is almost a meal, and a meat course, plus one bottle of mineral water, cost us in the neighborhood of $4 apiece, or for two of us something like sixteen rubles.

A few automobiles, practically all used as taxis, plied their trade, although they were very expensive to ride in. For instance, it cost $2.50 in American money to go from the depot, a distance of five blocks, to our hotel. Here we were given a guide, a young man about twenty-three years old. In conversation with him it developed that he was a student at the University of Moscow where there are twelve thousand students in attendance. After we had visited a number of the beautiful art museums filled with masterpieces of Russian art from periods before and since the Revolution of 1917, and after a visit to the Kremlin, where Lenin today is imbedded in ice, we strolled along the streets to gaze at the silent crowds.

Our guide, we found, was a zealous Communist. "You speak of liberty," I said, "and all the fine things you have in the Communist régime; in your studies have you ever read of

America? We have a very excellent government and a type of liberty and freedom well worthy of consideration." Almost in anger he turned on me and cried: "Freedom in America? Don't tell me about freedom in America! We have means of knowing all things that are going on in America, things from San Francisco to New York, and we know that just seven people in America own, rule, and operate the country. Don't talk to me about your freedom."

There flashed across my mind, of course, the answer to this "seven men," since I knew that just a small group in Moscow runs the entire Soviet dictatorship, but it did not seem to be the wise thing to discuss this subject further.

The Russians are a dramatic people, and my young Soviet student was no exception. Later in the day, while he was showing us beautifully engraved pictures of the Five-Year Plan and its up-to-the-minute accomplishments, he said: "In five years from 1928, that is by the fall of 1933, we will have so industrialized our nation that the entire world will be forced to purchase from us, or else go Soviet themselves."

The first views he showed in this drive for world industrial supremacy were of the great oil fields of Baku. Then he pointed to elaborate pictures of oil derricks, refinery installations, and men and women engaged in every conceivable form of recovery of the oil products from their native haunts.

"The production of the oil fields of Baku," he said, "in 1924–25 was only 896,000 tons; in 1928–29 it reached 3,350,000 tons, and will approach 4,500,000 tons in 1930."

Then he turned to beautiful illustrations from Ivanovo-Dosnesiensk, which, he said, is the center of the Soviet textile industry. Here he displayed a general view of a spinning mill for 127,000 frame spindles built at a total cost for construction and equipment, of approximately twelve and a half million rubles.

"Twenty-three hundred people are employed," he said, pointing to rows upon rows of girls trained to work as spinners, according to the methods of the central labor institute in Moscow.

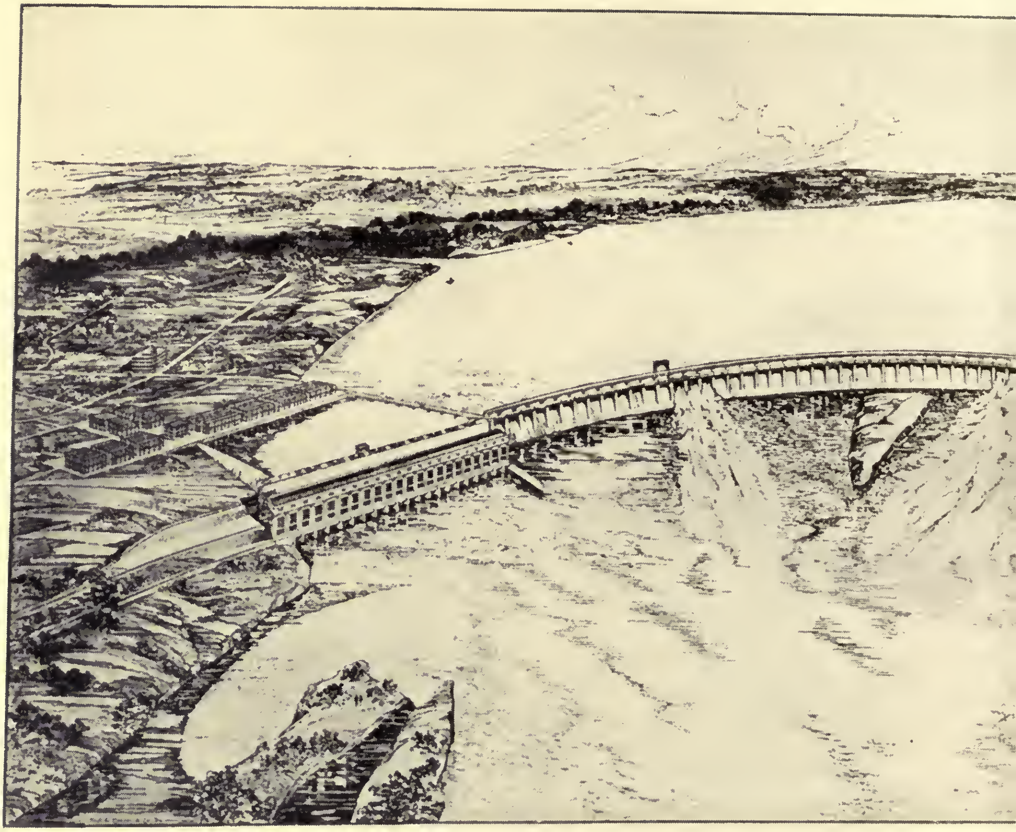
Buildings under construction, on paper at any rate—page after page of them—and a hydroelectric power station serving the territory of Transcaucasia next were spread before our eyes. "Formerly this power station had a capacity of 3000 kilowatts; at present," said our guide, "over 20,000 kilowatts are being exploited and six hydroelectric stations have been built since the revolution."

Then, with great pride, he continued: "In the coming ten years the U. S. S. R. will build electric power plants and will attain the same output as that in electric power plants in the United States of America. This means that in fulfilling Lenin's electrification plan we are already catching up with, and in the near future will begin to outdistance, America." Here he unfurled a map of the electrification of Soviet Russia, a map which is reproduced in this work facing page 41. It features the great Dnieprostroy, with its 750,000 horsepower capacity, and dozens of other small plants throughout European Russia and

THE
DNIEPROSTROY
[Pages 61, et seq.]

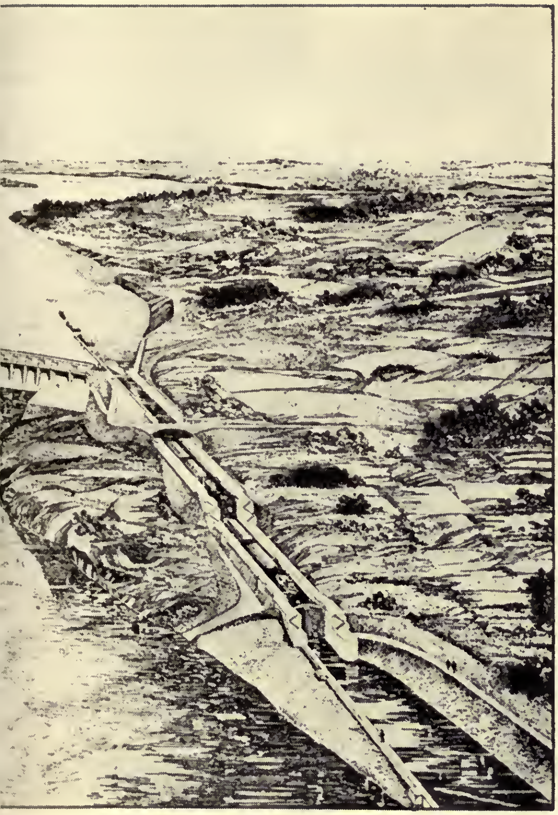
The Building of the Dam

The building of the great dam across the Dnieper River. As projected, the dam will be 2,300 feet—almost half a mile—across, 186 feet high, and 120 feet thick at its base.



Above. Engineer's drawing of the completed Dnieprostroy, a project which calls for the installation of 750,000 horsepower in generating equipment. Hugh Cooper, an American engineer of Keokuk, Iowa, fame, is in charge. It is situated 150 miles west of the Black Sea.

Right. Another view of the dam looking across the river.



Colonel H. L. Cooper
Chief of the American Consultation
Bureau of the Dnieper Works.
[Pages 60, 67.]

A Sectional View of the Dnieper Dam

". . . Great rocks were being pounded into fragments by many hundreds of workers, both men and women, and packed in carriers to the rock dump several hundred yards away. Why not the steam shovel, or at least the wheelbarrow?"

the Eastern Ural Mountains, built for a total capacity in the next five years of some 2,139,000 kilowatts.

Then he brought forth a publication of some forty-eight pages giving in detail distinct and excellent views of the Dnieprostroy construction. "The Dnieprostroy will furnish current to existing national enterprises, will irrigate hundreds of thousands of acres of dry steppe land, and will bring into being new giants of socialist industry through which, though projected on a larger scale, the Dnieprostroy will fulfill its part in the framework of the first Five-Year Plan."

In succeeding pages were dramatic views of the damming of the Dnieper River, massive bowlders being removed by the steam shovel, vast excavations for securing proper foundations, and the great bridge below the construction work with forty two-ton cranes hoisting into position the final span of the enterprise.

Dnieprostroy was undoubtedly worthy of closer study, and to that great undertaking we next bent our steps. In Berlin we had heard it spoken of with respect, perhaps a little awe, as the largest single installation for electrical power development in the world—a plant destined to develop 750,000 horsepower, a Goliath of electricity, and Lenin had said "Communism is Sovietism plus electrification."

CHAPTER VIII

THE FIVE-YEAR PLAN

UPON INQUIRY at the railroad station, we found that there were no first- or second-class tickets available and that the trip eastward toward the Black Sea would mean a ride of thirty-six hours. We found also that there was no such thing as first, second, and third class. We were informed that in Soviet Russia there is only one class—the worker's class. Tickets on the train, as a consequence, call for what are known as "soft seats" or "hard seats." Since there were no soft seats available we were forced to purchase hard seats. These consisted of planks about six feet long and thirty inches broad. To relax completely was out of the question, day or night.

With such accommodations two of us, myself and a young professor from Oklahoma State College, started out to inspect the Dnieprostroy. Neither of us spoke a word of Russian and we knew very little German and practically no French, so it was interesting to see what we could find out on this trip without language or guides. What we did find was at any rate the Simon-pure of information.

By the aid of a Russian-English dictionary and the laborious patching out of detached words, by pantomime, and the exchange of photographs and snapshots, and the sheer force of ideas determined to make themselves understood, we succeeded in learning a great deal about our fellow travelers and in tell-

ing them a great deal about ourselves. We learned that one was a certified accountant with a brother living in Los Angeles, who wrote that he was living in the paradise of the world; the woman across from us was a doctor returning to her charge of a sanitarium of 250 patients. The man to our right was manager of a great tractor plant; the younger one, next to him, a student at the University of Moscow.

We also had further proof of the high regard in which the Russian holds the "industrial idea" by the respect that was at once accorded us when they discovered that we were engineers.

It is largely through the efficient and ceaseless endeavor of American engineers now in the employ of the Soviet government that the great industrialization program is pressing forward. For instance, the Dnieprostroy is under the immediate direction of Hugh Cooper, the American who built the famous Keokuk dam on the Mississippi River; while the great reclamation project of Turkestan in Soviet Russia is under the supervision of Arthur P. Davis, recently chief engineer of the Mokelumne River project, the mountain water supply project for Oakland, California, an engineer who, as director of the reclamation service in America for twenty-five years, had a part in practically every large irrigation enterprise constructed in Western America. And so the roll could be called in practically all of the larger industrial enterprises now under way in Russia. American engineers have been asked to come over and undertake, at satisfying salaries, scores of important posts in this great rejuvenation which in five years will supposedly

make Soviet Russia industrially independent of the rest of the world.

We arrived at Alexandrov, the nearest railway station to the Dnieprostroy, about midnight on a Saturday in July, 1930. A telephone message to the engineering department, in charge of Colonel Cooper, brought word in welcome English that a Ford machine with an American driver would shortly call at the station.

As we approached the Dnieper River we could see spread out before us endless miles of electric lights. Soon we were at the guest house for visiting Americans. The stillness of the night was frequently broken by blastings of such terrific violence that one might think the western front of the World War had been revived and transferred to the region. A barefooted, stockily built Russian woman preceded us upstairs, packing traveling trunks with such ease and adroitness that I felt ashamed of my own grumblings of a few minutes before that one should be weighted down with such burdens when in Russia.

The guest room to which we were conducted overlooked the huge dam whose battlements were nearing completion. Powerful electric arc lights everywhere made possible work by night as well as by day.

To many the plans for building a hydroelectric power station on the rapids of the River Dnieper seemed a fantastic proposal when Professor I. G. Alexandrov, the projector of the scheme, first told of his vision of developing power and mak-

ing the Dnieper River navigable at these great rapids situated about 150 miles from the Black Sea. Yet in April, 1927, a beginning was made, and before the end of the year ten thousand men and hundreds of machines were already on the job building a new dam.

Houses and clubs, public baths and store-sheds, dining-halls and working plants rose from the bare steppe; dynamite rent the rocks, and train load after train load of building material rolled up to the scene of the proposed labors. From Dniepropetrovah to Zaporozhye, a distance of some fifty-five miles, the Dnieper is not navigable owing to the many long and short stretches of rapids, though the going is good for river traffic both above and below these two towns. It is below the rapids, near the town of Kichkass, that the waters of the Dnieper are being harnessed.

As projected, the dam will be 2300 feet—almost half a mile—across, 186 feet high, and 120 feet thick at its base. This structure will raise the elevation of the water level by 110 feet so that all the rapids will disappear. The water pressure thus made available will be used to drive nine water turbines of 90,000 horsepower each. On the left of the dam, as shown in the picture between pages 56-57, the construction of the power house itself is proceeding, while to the right are the locks that will enable shipping to move up and down stream.

In August, 1932, it is hoped, five turbines will be put into service; the other four about a year later. To begin with, the Dnieper hydro-station will supply 2000 million kilowatt hours

of electric energy per annum. When the four additional turbines are added, the station is designed to deliver annually about 3000 million kilowatt hours. The power thus obtained will effect an annual saving of three million tons of coal.

The estimated cost of the whole is 203 million rubles, or approximately $100,000,000. The hydraulic units being installed are the largest and most up-to-date available; the last word in American design and manufacture.

The Dnieprostroy is designed to furnish power for a huge combination of industrial plants in the neighborhood of the project. This group of industrial plants, when eventually completed, will be the chief consumer of the station's electrical energy at a proposed rate of 0.8 of a farthing per kilowatt hour, or about 0.4 cents per kilowatt hour, a figure, by the way, well above the cost of industrial power at Niagara. The combine will, according to Soviet statistics, include the following: a metal plant producing one million tons of pig iron a year; the Dnieper steel works, capable of turning out 100,000 tons of special steels; a works to produce 15,000 tons of aluminum yearly; plants producing ferro-alloys; and a nitrate fertilizer factory. The area to be occupied by the new plants in question is about nine miles long by two and one-half miles broad.

At the time we visited the Dnieprostroy, sixteen thousand workers were employed on the construction. Something like thirty thousand men will, it is estimated, be at work in the near-by industrial plants when finished. This means that

within the next few years a new industrial center for the Soviet Union is proposed in this Dnieper development.

In addition to these local industries, the Dnieper's energy will be used to feed the electrical needs of the big metal works to the west; the iron ore mines of Krivoy Rog, and the manganese workings of Mikopol. The 154,000 volts transmission line that is now building, the "Western Ring" as it is called, will link up the Dnieper scheme with the electric-power stations of the Petrovsky metal works in Dniepropetrovsk (20,000 kilowatts), the Dzerzhinski works in Kamensh (150,000 kilowatts); and with the Alexandriisk lignite-driven station of 200,000 kilowatts and the two stations of 75,000 and 44,000 kilowatts, respectively, at Krivoy Rog.

Again, the Dnieper station, by a similar 154,000 volt line, will be linked up with the coal fields of the Donetz basin. Thus will be extended vital assistance to the coal-driven power stations in that coal field, which, it is said, cannot keep up with the growing demand for electricity. Though projected on so large a scale, the Dnieper scheme, it is claimed, fits entirely within the framework of the first Five-Year Plan.

The Dnieper dam, a solid wall of concrete 120 feet thick at the base, rests on the granite bed of the river bottom and is mortised deep into the banks. The dam is topped by water piers with forty-seven spans, whose openings can be closed by iron gates thirty feet high, forty-two feet wide, and weighing seventy tons each. The building of the dam was effected by narrowing the river with cofferdams to about two-thirds of its full

width, working from both banks. The cofferdammed areas were thus separated from the river proper, which continued to flow through the open middle channel. The areas within the cofferdams were pumped free from water, the river bed was cleaned of all silt, and on the granite rocks laid bare at the bottom of this trench, were placed the concrete foundations of the dam. These foundations were raised to a point six feet below the usual summer water level of the river, and upon these the water piers were erected to a height of fifty-four feet.

In January, 1930, the cofferdams in the left channel were lifted and the water allowed to pass through the piers on that side. Simultaneously, the middle channel was closed by cofferdams. When all forty-eight piers are erected, the cofferdams will be removed and the concrete masonry, under cover of the iron grating between the piers, will be gradually raised to the full height of the dam. Practically all of these piers were nearing completion when we visited the Dnieprostroy in July, 1930. Furthermore, the hydraulic penstock piping had been installed for the first unit, as shown on the left side of the dam in the illustration.

The power house, shown on the left, is a building over an eighth of a mile in length, and it will contain water turbines of 90,000 horsepower each to be operated by the water pressure furnished by the dam. On the same vertical shaft with the turbines will revolve the generators for transforming the hydraulic energy into electric energy. The water will be conveyed to the turbines from a specially dammed-off area of water known

as the fore bay, shown on the left side, above the dam, in the illustration.

By flooding the rapids the dam will create a through waterway for traffic along the Dnieper. Water-borne traffic will pass over the dam through a three-chamber lock, as shown on the right in the illustration. To prevent any swirl of the waters at the ship entrance the inlet will be protected by a special flood dam. Each of the three chambers have a lift of 37.5 feet. This massive channel was being cut out of solid rock at the time of our visit.

The existing railway bridge at Kichkass, which lies above the dam, will be flooded by the rising waters, when the project is completed. Hence, it has been necessary to replace it with two bridges below the dam, one spanning the new Dnieper, the other the old Dnieper. Both bridges, now under construction, are highly interesting in design. With a span of 672 feet, the old Dnieper bridge will be one of the most stable structures of its kind in all Europe. The stone abutments have already been built and a beginning has been made on the assembling of the metal frame.

The general construction details appear to have been well checked by our American engineering experts. I was surprised, however, at some of the details of engineering practice carried out by the Soviet group. Upon observing a concrete tower far downstream, I asked its purpose. "That is the center of curvature alignment," said our Soviet engineering guide, "from there we direct the work at the dam." In American

practice the center of curvature is never located except on paper, since a quick and direct method of laying off the chords on the dam structure itself may be easily arrived at through mathematical computation.

Again, great rocks were being pounded into small bits by many hundreds of workers, both men and women. These rocks were in turn laboriously gathered up, placed in sedan chair carriers, and packed by groups of two workmen each to the rock dump several hundred yards away. Why not the steam shovel, or at least the wheelbarrow? One is led to question whether five thousand American workers could not, without any more physical strain, do the work of the sixteen thousand we saw down in the many river pits around and below us.

Said Hugh Cooper, the genius in charge of the Dnieprostroy, when interviewed upon his return to America lately, and asked whether "forced labor" was in vogue among the Soviets: "Forced labor—I've got sixteen thousand laborers working for me, and I'd like to see some one force them." To anyone who watched, as I did, the dogged inefficiency of so much of the Dnieprostroy labor, there is a world of significance in this remark.

The Five-Year Plan of electrification in Soviet Russia calls for a total putting into service of 2,846,000 kilowatts by the fall of 1933, with some 5,300,000 kilowatts in addition still under exploitation. Details of these proposals are to be found in Appendix I.

Upon reading again the pages of this chapter, I am conscious of having used such superlatives as "vast," "great," and "huge," in describing the Five-Year Plan of electrification in Soviet Russia, particularly in its progress at the Dnieprostroy. The reason for this is not far to seek. As we passed over the vast steppe-land of European Russia, with little or no appearance of modern industrialization, or through her thronged cities peopled with sad and distressed faces—faces that seldom smiled in relaxation—to come upon an oasis in the desert, as it were, here and there in the upbuilding of her industrial life, is to have one's sense of proportion sadly impaired. When I get back, in thought, to America again I am overwhelmed with our progress, so much vaster, so much more surely founded. I remember as a freshman at the University of California hearing Joseph LeConte, the well-known geologist and naturalist, describe to us his first impressions of the big trees of California:

"My first impressions of the big trees were somewhat disappointing; but, as I passed from one to another; as, with upturned face, I looked along their straight, polished shafts, towering to the height of three hundred feet; as I climbed up the sides of their prostrate trunks, and stepped from end to end; as I rode around the standing trees and into their enormous hollows; as we rode through the hollows of some of these prostrate trunks, and even chased one another on horseback through these enormous hollow cylinders, a sense of their immensity grew upon me. If they stood by themselves on a plain

they would be more immediately striking. But they are giants among giants."

"Giants among giants" indeed well describes our electric power achievements in America. I find in Western America alone, already constructed and in operation, at least five great dams that outrank the dam of the Dnieprostroy in engineering achievement. I find in America over two score of electric power network distributing systems, each one already delivering more electrical energy to industrial America than the Dnieprostroy is designed ever to deliver.

It is the same when one turns to consider the much advertised care of the Soviet for the worker. If there is one thing I can speak authoritatively on, it is camp life in electric power construction work of America, because twelve years of my life was spent inspecting and visiting practically all of the outstanding work of this type in Western America at least, and I know that what I saw with my own eyes when I was at the Dnieprostroy could in no sense of the word approach the sanitary protection for the workers observed in American camps of similar type, nor in comfort and hygienic layout provided for American workers.

And as for the food given the workers, I can only say that if American workers under standards of living in vogue in America were even offered such food, not a single worker would remain on the job.

CHAPTER IX

OUT OF RUSSIA WITH A WARNING

AND so, at last we found ourselves on our way back, to the north and to the east, over vast plains and through great cities, all much alike, all telling the same tale. There was Kharkov, for instance. Kharkov is today the capital of the Soviet Republic of the Ukraine. Here at the railroad station, as in all other towns, was the typical Russian scene. Vast crowds, going, going, going, nobody seemed to know where, yet each one patiently awaiting his turn to purchase his ticket or get aboard the train.

Often we would see hundreds of people lying prostrate on the floor of the station building fast asleep but always in order, each one awaiting his turn to press forward upon the train when at last it should arrive at the station. At Kharkov we had to wait several hours at the station house and so had every opportunity to look around us. It was a strangely sad experience. There were beggars on all sides, old men and women and little children. I shall never forget one little boy of about ten years old who came up to beg for the chicken bones I had left on my plate. I was hungry and had picked them almost clean; nevertheless he took them greedily and, gnawing them like a dog, consumed them all.

From Kharkov we went to Kiev, and upon leaving Kiev we traveled on westward to the frontier.

Here once again the fixed bayonets met us and the soldiers questioned us and examined our effects. Our films, kodaks, and printed material we were carrying out with us were especially searched and carefully inspected. Especially, too, were our inspectors desirous of seeing that no Russian money left the country. My friend, for instance, after he had cashed in his Russian money for Germany money, found that he still had two rubles left. When the soldier inspectors discovered the fact he was summarily ordered either to give up the money or to purchase something in a store near by. This latter my friend did, buying a little piece of chocolate for two rubles, twenty kopeks, or $1.10 in American money. The size of the piece of chocolate so purchased was about three inches by four, by one-eighth of an inch thick, selling for five cents in America.

. . . . . .

So we went on our way across the frontier.

. . . . . .

As we left Soviet Russia we could not help but breathe a little more freely, as though a great load of depression had been lifted from us. The weeks behind us seemed in many ways like a bad dream. Yet we were conscious of having passed through an experience full of meaning; full, too, of warning for the world at large—particularly a warning of deep significance to America.

The Appeal to Save the Waste

Throughout Soviet Russia an appeal is being made to save the waste. This poster urges every citizen to save old ropes, iron, tin cans, bone, shoes, and other cast-off material, and bring these articles to a representative of the government who will give them a certificate of indebtedness for the material. It informs them that the government will use the money from the sale of this material to purchase tractors to help put over the Five-Year Plan.

PART II

Waymarks in American Power Progress

CHAPTER I

A MASTER STROKE IN POWER DEVELOPMENT

Speaking in general terms, American power development falls under four great subdivisions: New England, including Niagara; the Southern states, with their rivers in Georgia, Alabama, Tennessee, and the Carolinas; Chicago and the Middle Western district, largely steam electric; and the eleven Western states of the Pacific Coast where are located two-thirds of the entire natural water resources of the nation.

I have chosen the Pacific Coast electric power systems as a typical example of American engineering, because in its achievements lies the answer to the Russian challenge.[1] What the Pacific Coast is doing today the world will be doing tomorrow.

On the Far Western Coast of the United States of America, three thousand miles from the great commercial and financial centers of the country, is located the commonwealth of California, the second largest state in the Union and the one in which electrical development has attained outstanding eminence. Within the past few decades California has developed

[1] For, while there is no developed water power comparable to the Dnieper on the Pacific Coast, vast sources of power have been created by damming mountain streams, chiseling tunnels through mountain sides, and dropping water through pipes down vertical distances approaching half a mile. In many instances even now these enterprises surpass the Dnieprostroy in the development of electrical power. Then, too, the utilization of natural gas otherwise running to waste has taken place to a degree so revolutionary in the efficiency obtained as to establish records in economy and to challenge water power in its supremacy.

into a veritable empire through its agriculture, industry, and commerce.

California has a medial, north and south length of about 780 miles, and a breadth varying from 150 to 350 miles, comprising in all an area of 158,297 square miles, 2645 of which represent water surface. Its area is 80 per cent of that of the Republic of Germany. In 1850, its population was 92,597. On January 1, 1930, its population was estimated to be in excess of five millions. It has an annual production of gas and mineral products valued at more than $200,000,000; its farms produce crops valued at more than $600,000,000; and its manufactories produce goods valued at $2,700,000,000. Its foreign exports and imports are in excess of $1,000,000,000.

Because of its geographical isolation, its great stretches of barren land devoid of water, and the mountain barriers making commercial intercourse with the older and more advanced sections of the United States difficult, California has had to shift for herself. Early in her history it became apparent that unless her people could harness the vast water power in her mountain fastnesses, supplemented by electric power generated from her oil and gas resources, and convey this power economically over distances heretofore considered impracticable—often two to three hundred miles—little hope could be held out for an extensive development of her natural wealth.

The problem was one which involved not only California, but her ten sister states whose surface is drained from the Rocky

Mountains westward into the Pacific Ocean. In this district two-thirds of America's potential water power is located.

During the past two decades the civilized world has been vigorously engaged in harnessing its natural resources, particularly its water power; and nowhere has progress been so rapid and on such an unprecedented scale as on the North American continent, for vast as has been this harnessing of power in other countries, the total electric energy annually generated in the United States and in Canada practically equals the combined output of the world. This holds true whether we consider electrical energy generated from water power alone, from steam power using coal, oil, or gas fuel, or from the two combined.

Electrical power production statistics as published in the 1929 edition of "Power Resources of the World," for twenty-four leading countries, bear out this statement. The total electrical output as there listed, exclusive of the United States and Canada, is 82,623 million kilowatt hours. Other countries not listed would not expand this figure beyond an additional 15,000 million kilowatt hours. It is evident, therefore, that the United States and Canada with a combined output of 92,300 million kilowatt hours approximates the remaining electric power production of the rest of the world.

ANNUAL ELECTRIC POWER PRODUCTION THROUGHOUT THE WORLD

(In millions of kilowatt hours per annum)

United States	80,205
Canada	12,093
Total	92,298
Germany	12,444
France	11,347
Great Britain	8,750
Italy	8,100
Japan	8,000
Norway	8,000
Russia	4,112
Sweden	4,350
Switzerland	3,350
Belgium	3,160
Austria	2,500
Poland	1,900
Mexico	1,400
Czechoslovakia	1,300
Holland	1,200
New Zealand	540
Roumania	500
Dutch East Indies	500
Denmark	422
Finland	360
Tasmania	350
Bulgaria	38
All other countries not listed	15,000
Total	97,623

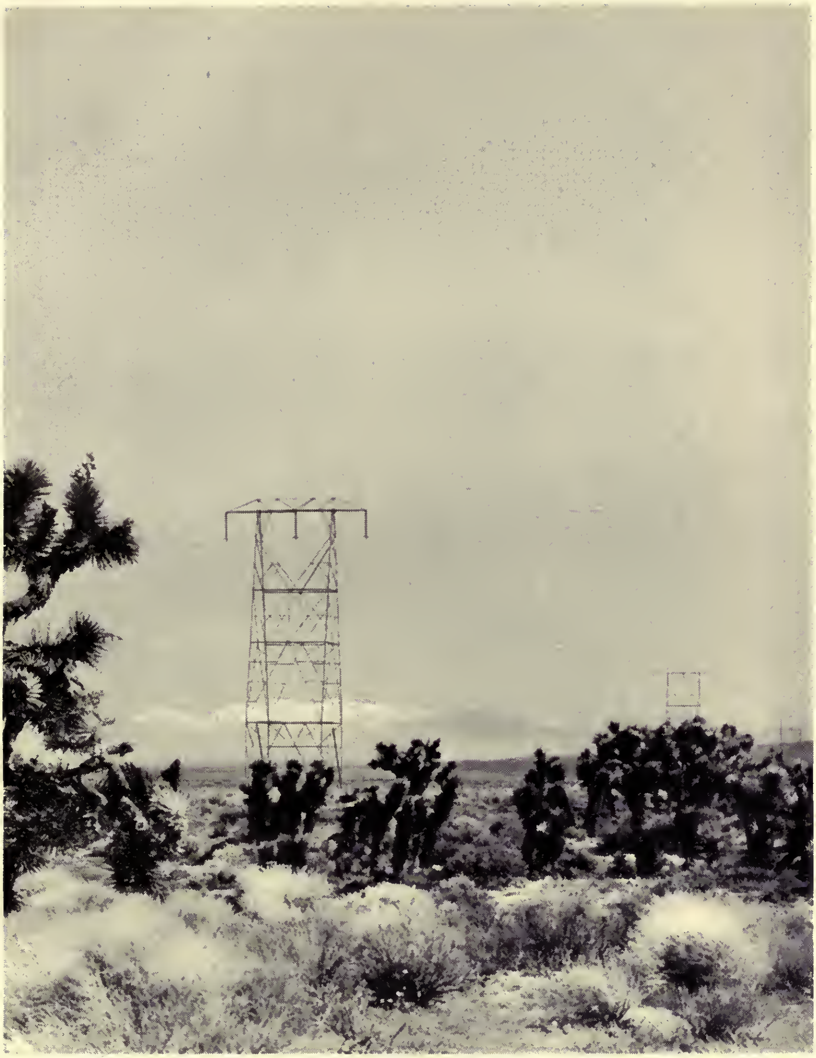
While much of this power development in America has taken place at Niagara Falls or in the rapidly developing Southern states, the district west of the Rocky Mountains, draining into the Pacific Ocean, particularly California, leads the world in intensive distribution of electric power both in the home and in agriculture over such an extensive area.

Spanning the Carquinez Straits—a Northern Arm of San Francisco Bay

The distance spanned is 4,427 feet, and for seventeen years constituted a world's record.

The Snow Towers in the Mountains

Where transmission lines are subject to severe snowstorms the wires are suspended parallel to each other as here shown, in order to protect one from the other during the melting of the snow. The lines shown are a portion of the Pit River development, Shasta County, California, a world record transmission of 220,000 volts over a distance of 250 miles. Note the lower disk on the suspension insulator. This is a particular device to handle extra heavy electrostatic stresses involved in such high voltage transmission. [Page 83.]



The Desert Is Conquered by the World's Largest High Voltage Transmission Lines

The driving of tunnels, the building of record dams, and the crossing of picturesque and barren deserts were the feats necessary to establish a world record for transmission of electric power at 220,000 volts into the City of Los Angeles, 250 miles from the source of power generation. Here are the power lines crossing the Mojave Desert. [Page 83.]

The Long-Distance Transmission of Power

In 1892 this power plant near Mount San Antonio in Southern California transmitted power to San Bernardino, twenty miles distant, at ten thousand volts from a generator operating at but five thousand volts. This was the first time in history that power was transmitted such a distance over lines operating at a voltage higher than that obtained in the generator. [Page 81.]

The Social Life of Employees

One of the significant factors leading to the development of a high morale among the workers in California's electrical industry, has been the interest shown by employers in the housing facilities and vacation opportunities offered employees. Here is shown a clubhouse built by the Pacific Gas and Electric Company at Pit River Plant No. 1, as a summer outing and recreational center for district executives whose work confines them to the larger cities. The cost of this center has been repaid many times over in increased loyalty and efficiency among its users.

A Record in High Voltage Submarine Cable

To convey power from the High Sierras into San Francisco, a power cable 3½ miles in length under San Francisco Bay, operated by ten thousand volts, became necessary. The illustration shows the laying of the cable which was passed from the coil to the half reel directly above the core and then down through the trough to the water. [Page 82.]

The Highest Head Plant on North American Continent

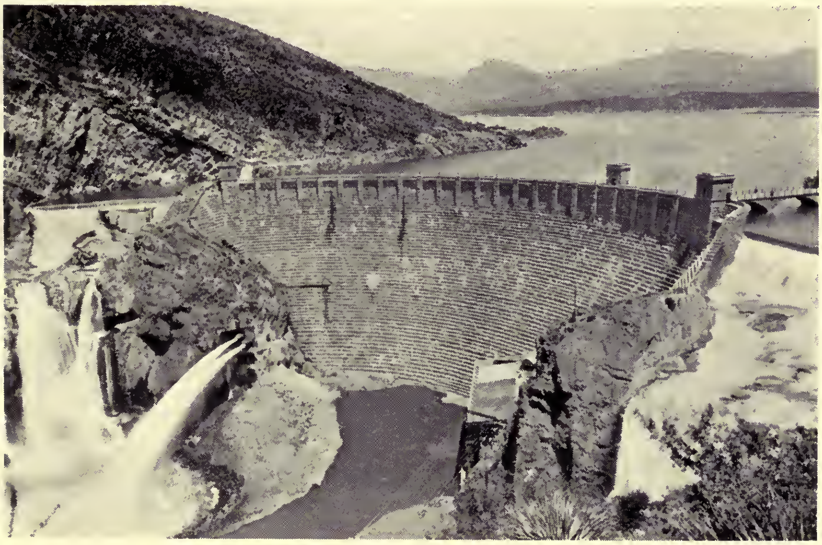
Buck's Creek Power House, on the north fork of the Feather River, Plumas County, California, operates under a head of 2562 feet, the highest head developed in North America. Twin penstocks 4800 feet long carry the water to the power house. [Page 82.]

Electric Magnet in Steel Mills

Electromagnet hoisting iron from cargo shipments into yards for storage. The load shown on the magnet amounts to more than five tons. [Page 88.]

The Highest Dam Under Private Development in America

The Spaulding Dam is of the constant-angle, arched type, 275 feet high, with a crest of 800 feet, and impounds 74,488 acre feet. The waters conserved at high altitude in the Sierra Nevadas pass through a series of power plants in the canyons below to be finally utilized for irrigation on fertile California farms of the Sacramento Valley.



Huge Dam for Irrigation and Power Supply

The Roosevelt Dam in Arizona is 342 feet high. It is one of the world's most impressive structures in irrigation and power development. The Salt River project on the Pacific Coast of America is largely made possible by this gigantic structure. Its waters irrigate many thousands of acres of arid lands and furnish electricity to the homes of prosperous farmers. This is one of America's most successful reclamation projects.

Reclaiming Arid Lands

California has become world famous for its method of reclaiming arid lands by pumping upon them water from deep wells. Here is an electrical agricultural development at Mendota, Fresno County, showing the conversion of arid lands into fertile areas by means of water from deep wells. The large reservoir makes possible constant pumping throughout the growing season, resulting in a high load factor. On this land are grown cotton, corn, alfalfa, and wheat.

The Highest Rock-Filled Dam in the World

This dam is of the rock-fill type, having a maximum height of 337 feet above rock foundation, and a crest of 1300 feet. It contains in excess of 2,900,000 cubic yards of rock. It is known as the Salt Springs Dam, and is located on the Mokelumne River, California.

The Beautiful Hetch-Hetchy in Yosemite National Park

The Hetch-Hetchy reservoir, impounding water for the city of San Francisco, 150 miles distant, is a striking example of what can be done to conserve water without destroying the natural scenic beauty of the district. The water from this reservoir, while on its way to the households of San Francisco, incidentally develops 100,000 horsepower.

CHAPTER II

PECULIAR ENGINEERING PROBLEMS SOLVED

SOME OF THE engineering difficulties surmounted in developing power in Norway, Switzerland, and Italy have been indicated. In California there proved to be a totally different situation. While there existed unprecedented possibilities for electric power generation, the source of water power was back in the high Sierra, hundreds of miles from the great cities and fertile valleys where the power was needed. Consequently hitherto unencountered obstacles had to be overcome in building dams, driving tunnels, crossing deserts, and passing over or under large bodies of water.

The longest line for transmission of power ever undertaken at that time was built in 1892 and supplied San Bernardino, California, with electric power generated from falling water in San Antonio Canyon at the foot of Mount San Antonio, twenty miles away. Here, for the first time in history, power was carried over a record-breaking distance at a higher voltage than that actually generated in the dynamo.

Realizing the economic value of the power supply that would result from the harnessing of the water resources in the Sierra Nevadas, engineers immediately began to study the new problems of power transmission in every section of California. To bring the power into the City of San Francisco, for instance,

the upper reaches of San Francisco Bay must be spanned at Carquinez Strait. No wire had ever been stretched such a distance —three quarters of a mile—in a single span for power transmission. Steel manufacturers, however, soon put their engineering staffs to work and produced a cable that for seventeen years proved to be a world record for a single stretch of wire, 4600 feet in length, conveying electric power at a pressure of 11,000 volts. The next obstacle encountered was when an attempt was made to transmit the power from the City of Oakland to the City of San Francisco, across the main body of San Francisco Bay, at a point three miles wide. Steel cable could not be stretched safely over a three-mile span, hence the power was passed under the bay, a feat accomplished after a series of investigations on the part of indefatigable engineers.

Then began a ceaseless struggle to transmit, economically, electrical energy over increasingly greater distances. The Southern California Edison Company, which took its power from the Big Creek development in the Sierra Nevadas east of the city of Fresno, found it could economically drop water from the mountain heights above, as was already being done in Switzerland. As a consequence there was developed a world record for capacity high head installation at power plant No. 2A of this company, wherein water is dropped 2410 feet vertically through water wheels of 112,000 horsepower capacity. The highest head development on the North American continent is the Buck's Creek power plant of the Great Western Power Company, now a part of the Pacific Gas and Electric

system, which operates under a head of 2562 feet with a generating capacity of 67,000 horsepower.

Each succeeding year has seen increasing distances and increasing voltages at which power has been economically transmitted. Today the world's record for long-distance transmission is held jointly by the Southern California Edison Company in California, which takes power from east of the City of Fresno to the City of Los Angeles, and the Pacific Gas and Electric Company taking power from east of Mount Shasta in Northern California and delivering it into the City of Oakland at 220,000 volts over distances ranging from 250 to 300 miles. The joining together of these two long-distance systems has produced the greatest interconnected system of power transmission lines yet built, stretching from Medford, Oregon, in the north, to the Mexican border in the south, a distance of 1200 miles. This system generates annually in excess of 8750 million kilowatt hours of electrical energy, representing working power equivalent to that of twenty million slaves and steadily increasing.

In this interconnected system the Southern Sierras Power Company transmits power at 87,000 volts and 57,000 volts, 539 miles, from Mono County, California, to Yuma, Arizona, a record achievement. This extensive production of electricity has resulted in the highest per capita consumption for any community of its area in the world, the average per year being 1600 kilowatt hours, twice that which prevails in America as a whole.

These record distances in transmission have so distorted the phase relationship of voltage and current that condensers of record proportions have proved necessary. The largest condensers in the world are the two 50,000 KVA condensers used for the 220,000 volt field line regulators of the Southern California Edison Company in Los Angeles.

Great auxiliary steam power plants have been built to carry the hydroelectric load in periods of excessive demand or at times of low water supply in the mountains. The largest and most efficient steam electric generating plant using oil and natural gas as fuel, an installation of 268,000 horsepower steam turbine generator equipment, with ultimate capacity of 1,000,000 horsepower, is installed at the Long Beach plant No. 3 of the Southern California Edison Company. This plant has the distinction of having the largest single shaft turbogenerator in the world, with a capacity of 134,000 horsepower. Efficiencies up to 550 kilowatt hours per barrel of oil are attained—new records in engineering effort of this type. *Ten years ago the record was but one-half this economic accomplishment.*

While originally steam electric power plants in California were designed as auxiliaries for hydroelectric supply, due to the marvelously increased efficiencies of high-pressure steam turbines and the vast oil and gas resources that have been uncovered in the state since 1923, steam electric power is now ranked as a prime source of power in the larger industrial centers, openly challenging the hydroelectric costs in many localities.

Since the conservation of water is of prime importance for power and for irrigation in this section of the world, mammoth dams have been erected. The highest rock-filled dam, that of the Salt Springs project of the Pacific Gas and Electric Company, now under construction, has a height of 337 feet above its rock foundation. Likewise in this general area there has been created the largest artificially conserved water supply for irrigation, that of the Elephant Butte Dam in New Mexico, where a dam 342.5 feet in height retains three and one-third million acre feet of water in one impounding reservoir. And again, the highest dam, that of the Arrowrock Reservoir in Idaho, with its height of 346.5 feet above foundation bedrock, has been in successful operation for some years.

A number of other projects are under way that will surpass these. Among them may be mentioned the Boulder Dam in the Colorado River, which will have a height of 550 feet, or more, above water line, or 750 feet above bedrock, thereby conserving twenty-five to thirty million acre feet of water by means of one stupendous engineering structure. The power developed by this enterprise will be in excess of a million horsepower, and will be transmitted into California, as one of the participating states, at a new record of 300,000 volts.

All of these projects—completed, under construction, or contemplated—play their part in making the Western United States unique in the electrical world. They have not been realized overnight. Their growth has depended on individual genius, group initiative, and time. Like California's giant

Sequoias, they have reached such size only through steady and strong development. Power plants may be built in a short time, but the distributing systems and the power market, without which the power plants are useless, are built up more slowly. Supply and demand must remain in close partnership and demand for electric power is a phase of the industry with its own unique problems.

CHAPTER III

ECONOMIC ASPECTS IN INDUSTRY, AGRICULTURE, AND THE HOME

A MARVELOUS EASING of the burdens of industry followed development of power in California and its neighboring states on the Pacific Coast of America. In 1930 the Southern California Edison Company delivered 2,617,495,280 kilowatt hours to its consumers. In other words, this one California company delivered one-half as much electrical energy in 1930 as all of the combined power enterprises in Soviet Russia in that year. Indeed, this one company delivered more electrical energy to its consumers in 1930 than the famous Dnieprostroy is designed to give even should the Five-Year Plan clear all the hurdles in construction and operation and prove 100 per cent effective.

The Pacific Coast's electrical energy was used in the following manner:

Lighting	11.9 per cent
Commercial	33.9 " "
Agricultural	17.7 " "
Railways	10.8 " "
Other electrical corporations	1.0 " "
Municipal for resale	22.0 " "
Municipal miscellaneous	2.6 " "
Used by company	0.1 " "

Ancient Athens grew wealthy and powerful through the enforced labor of perhaps ten thousand slaves. California citizens enjoy benefits produced by the equivalent of twenty mil-

lion slaves, represented today in the subtle force of electric power. To mention but a few: Electrically driven trucks carry baggage and express through the great Ferry Building of San Francisco, replacing a hundred men with one truck driver; the steel industries, such as the Pacific Coast Steel and the Columbia Steel Company (now subsidiaries of the United States Steel Products Company and the Bethlehem Steel Company respectively), use electrical magnets to hoist great loads of iron from dock to steamer hold. The fruit-canning industries of California have developed a sanitary process, electrically operated throughout, by which the hand of man does not touch the fruit during all of its treatment from the time it leaves the orchard until it appears as a canned product.

Gold dredges of Northern California, successors to the hardy pioneers of '49, in gathering gold from the placer deposits, are operated electrically. They extract the ore from the gravel with marvelous efficiency. In many cases these gold dredges, the largest in the world, gouge up the river bed material, wash the gold from the gravel, and redeposit the gravel in the streams, all for less than 5 cents per cubic yard. A handful of men do the work that would have required thousands in '49.

The harmful products of dust, and the poisonous particles emanating from the smokestakes of industrial plants, have been eliminated through an invention of Frederick G. Cottrell and his co-worker, Walter Schmidt—a process which electrically precipitates and economically recovers these particles. This is accomplished by establishing a strong magnetic field

Electrically Spraying Fruit Orchards

Because of the necessity of spraying orchards under difficult weather, soil, and cover-crop conditions, some Pacific Coast orchardists have installed a central or stationary spray pump which discharges into pipe lines laid throughout the orchard. Faucets or hydrants are placed at convenient distances to spray the trees with hose varying in length up to 100 feet.

Electric Cooling of Fruit Shipments

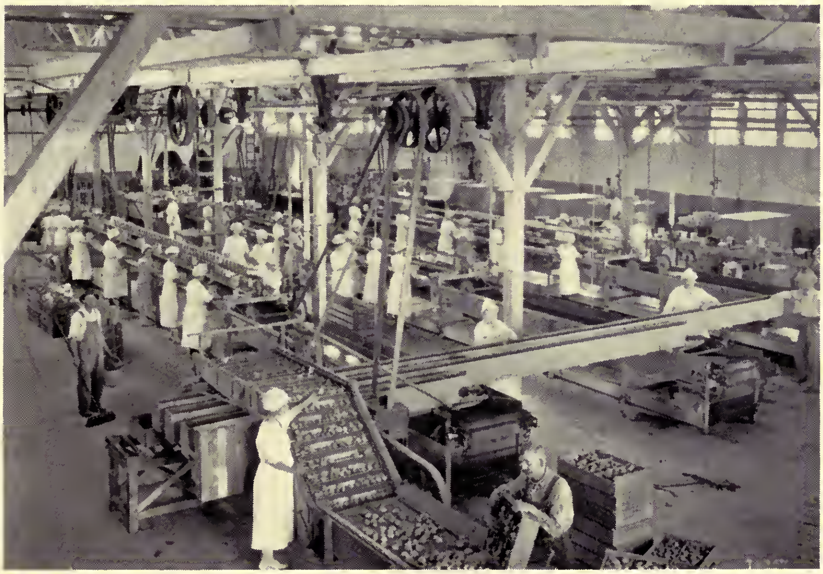
Here is a portable type of railroad car precooler used in California, consisting of 4 ¾ horsepower electrically driven fans. These fans circulate the air from the ice in the ends of the refrigerator cars through the fruit, the purpose being to remove the initial heat and to retard ripening.

The Electrical Brooder for Chicks

The electric brooder is used extensively by California poultrymen, and the sizes vary from fifty to five hundred chicks under a brooder. Approximately one thousand electrically heated brooders are now in use in California, with a combined capacity of ten million chicks a year.

Electrical Processing in the Raisin Industry

Over 90 per cent of the world's supply of raisins are grown in Fresno County, California. Electricity provides a sanitary processing system.



Labor-Saving Devices

Electricity is widely requisitioned in the handling and preparing of fruit for packing; a plant of the California Peach and Fig Growers at Dinuba, California.

Electrical Pumping

The water is pumped from underground sources upon land arid and uninviting in its natural state, but which later is made to yield abundantly. With 656,000 horsepower in connected load for irrigation, operating 39,600 motors, California's farms out-distance those of any other equivalent area in the world.

in the chimney where, while the gases continue upward, the solid particles, becoming electrified, travel at right angles to the flow and are thus collected and recovered!

Outstanding applications of electric power in the mines of this district have also been developed. For instance, engineers on the Bunker Hill and Sullivan Mines at Kellogg, Idaho, have developed in this famous mine a veritable Aladdin's cave. Not only is it one of the largest lead-silver mines in the world, but in electrical refinements of operation one might think that Aladdin's lamp was still performing miracles.

The transcontinental railway known as the Chicago, Milwaukee & St. Paul has been electrified for 754 miles over the Rocky Mountains and into the fertile regions of Eastern Washington, making possible an electrified transcontinental railway, the longest of its type in the world, and the only one in America. After passing over the summit of the Rocky Mountains, the down grade journey, as in Switzerland, makes use of regenerating equipment which automatically controls the speed of the train and recovers electrical energy by using the motors as generators, This has the added virtue of saving wear and tear on the brake equipment.

The California home with its electric range and a hundred other household conveniences has reduced the burden of the housewife almost to the act of pressing an electric button. From a survey of five-hundred homes in California we find that the average monthly consumption of electric energy per home varies from 64 kilowatt hours to 495 kilowatt hours and the

monthly bill from \$3.20 to \$11.21. In general, lighting rates in California are about 4½ cents per kilowatt hour for incorporated areas. In order to encourage household uses of electricity, domestic combination rates for consumers using lighting service and electric appliances for heating and cooking as low as 1½ cents per kilowatt hour are in vogue.[1]

A recent statistical analysis has shown that California farmers utilize electrical energy to a degree not even approached anywhere else in the world, 49,067 farms being at the present time supplied with electricity. In 1928, there were 956,225,225 kilowatt hours of electric energy delivered to these farmers at the remarkably low cost of \$14,303,580.50, or *1.41 cents per kilowatt hour.*[2]

Nowhere in the world are electrical uses so widely distributed and so varied in application. Every conceivable electrical device is at work to ease the burden of the farm—motors for pumping water; incubators; battery chargers; brooders; milking machines; feed grinders; refrigerators; dehydrators; wood saws; silo fillers; and, for the household, flatirons, washing machines, vacuum cleaners, sewing machines, radio, etc.[3]

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[1] In Appendix II we give the percentage of homes that have each of thirty-one different household electric appliances in use—first in the average home, next in the home especially designed and equipped electrically under the guidance of the electrical industry itself.

[2] In Appendix II is a summary of totals and averages of consumer, connected load, energy consumption, and cost to farmer of electricity sold by thirteen power companies in California, on agricultural power schedules as taken from reports of the California Railroad Commission.

[3] In Appendix II may be found general statistics on the number of electric appliances and electrically driven machines used on California farms, gathered by B. D. Moses, associate professor of agricultural engineering and associate agricultural engineer in the experiment station of the University of California as of 1925. From the 51,000 farms of California coming under his observation, he obtains this exceedingly interesting information.

Agricultural development of the future in California will depend largely upon the utilization of underground waters for irrigation, and in this the electrical pump is destined to play a major rôle. In 1910 the United States census statistics showed 2,333,333 acres of California farm lands irrigated by the gravity supply system, with only 333,330 acres irrigated by pumping. By 1920, 2,500,000 acres were irrigated by gravity, only a slight increase in ten years, while in this same period irrigation by pumping had grown to the total of almost 1,500,000 acres. This tremendous use of electric power in irrigation on California farms is indicated in the tabulation at the end of Appendix II, in which Professor Moses finds 656,000 horsepower in connected load used for irrigation motors alone.

Side by side with the development and use of electric power, each year there has accumulated new knowledge of the laws of hydraulics, of electric transmission, and of water, oil, and natural gas conservation, all of which is bringing about extended use of California's natural resources.

In particular, Professor Harris J. Ryan of Stanford University, in his high-tension laboratories, has tested long-distance transmission of electrical energy. Irrigation, drainage, rainfall, water law, protection of forests and national parks, have all come in for their share of study on the part of other investigators.

Such is the story of power consumption in California and the Western United States. The economic life of the people in adapting itself to the new conditions has been unbelievably

altered. However, with each step in the development of power resources there has been a slower step in power consumption. The education of millions of people to new customs is a laborious process, requiring far more time than does the training of engineers capable of creating need for such education.

The story of California has a world-wide bearing, for, as Owen D. Young, international authority on finance, in his Charter Day address at the University of California in 1930, said: "Let no man think that the living standards of America can be permanently maintained at a measurably higher level than those of other civilized countries. Either we shall lift theirs to ours or they will drag ours down to theirs."

CHAPTER IV

SOCIAL ASPECTS

THE FOUNDATIONS of the electrical power industry in California were laid almost before the district became a state, and it was early seen that a clear working understanding between the political state and those in charge of power development within its confines would be desirable. Three definite problems appeared on the horizon, threatening to retard, if not prevent, progress unless solutions for them were found.

The commonwealth of California found itself so dependent upon the supply of power that its very life blood was at stake, hence the necessity for laws whereby reasonable rates should be assured to consumers, as well as reasonable protection for the investors whose money was involved. As a consequence, the powers of the California Railroad Commission have been gradually increased *to such an extent that this commission at the present time is practically supreme in determining the rates charged for the use of electricity in California.* This it does on the assumption that a return to the investor of 7½ per cent or thereabouts on money invested is reasonable and right.

The Railroad Commission early adopted the policy that the public and power companies of the state are not necessarily antagonists; that the owners, managers, and consumers of the power companies and the public at large are equally interested in soundly financed, prosperous organizations that are able and

willing to furnish good service at reasonable rates. The Railroad Commission has never considered itself solely a court to which contestants should submit disputes, but rather a part of a public system consisting of the companies that produce electricity, the consumers who use it, and public bodies, of which the Railroad Commission is one, whose task it is to harmonize the interests of the other two and of the nonconsuming public in so far as it may be involved.

It is just as much, or even more, a part of the Railroad Commission's duty to prevent disputes as it is to settle disputes after they arise. In keeping with this policy, rates have as a rule been reduced before a contest arose. During the war and the period of high prices following, rates were generally increased, but with the later decline in price levels they have been again gradually reduced, generally on the initiative of the company, until now, for the state as a whole, they are lower than ever.

During these changes the structure of the rate system has been altered to eliminate sources of complaint and dissatisfaction. The quality of service has been improved and its area extended until, at the present time, there are few villages or settled areas in the state where power company service is not available. Rules governing the business relations between power companies and their customers have been codified and modifications made as found desirable. *There is on file in every office of every power company in the state a price scale for the commodity which it sells to the public and a complete statement of the right and obligations of the purchaser of that commodity.*

One thing that is vital to sound financing is the issuance of securities. No securities have been issued in California since 1912 without the approval of the Railroad Commission. In every case the granting of this approval has involved a scrutiny of the purpose for which the securities were to be issued, the value of the property, the probable earnings, and other factors necessary for intelligent action. In many cases the authority to issue securities has been denied. The improved standing of the companies' securities from 1913 to the present time is one of the results of this policy, and it has carried with it a reduction in the cost of money to these utilities.

In exercising its control over the establishment of new utilities and the entrance of existing companies into new territory, the Railroad Commission has been guided by the principle that competition of power companies is desirable only where it can be definitely shown that the public interest will be served. On occasion, competitive construction has been authorized. A survey of the state will show, however, that lower rates and better service have come about under this policy just as rapidly where no competition existed as where it did.

In providing for the safety of employees and of the public, the Railroad Commission has issued orders governing the standards of construction of overhead electric lines; of crossings where the factor of safety to the public is involved; has laid down specifications for dimensions and strengths of overhead line construction; all of which has increased the standard of service. In drafting these orders the Railroad Commission has

invited and received the coöperation of power and telephone companies, city and state officials, and the manner in which the orders have been accepted shows that they have merited the confidence placed in them.

Inductive interference between power and communication lines is another subject that has come in for investigation. In approaching this matter the Railroad Commission has always insisted upon the remedial measures that involve the least cost for the good accomplished. It has not viewed the question as one of mere legal rights and priorities. It has sought the coöperation of the utilities involved and has encouraged coöperation to such an extent that the practice has come to be that public service utilities work out their own difficulties and call upon the commission for approval or for the settlement of occasional disputed points. During the past five years the inductive interference problems occasioned by the construction of one thousand miles of line of 165,000 volts, or higher, have been handled between the power and communication companies with but one question having been referred to the Railroad Commission, and that only for a suggestion as to a basis for settlement rather than for a definite ruling.

The question of finance was naturally a major issue. Overnight, as it were, millions of dollars must be found for the building of these great power projects and distribution systems. California in its isolation from the financial world was at a definite disadvantage. It was proposed, therefore, to sell the preferred and common stock of these hydroelectric companies

to the consumers of the company itself. From the start this new proposal, first made by A. F. Hockenbeamer of the Pacific Gas and Electric Company, met with success. The subsequent sale of both common and preferred stock was brought about through what is known as the "self-interest" plea in industry.

Practically every phase of industrial and agricultural life in California is tied in with the development and supply of electric power. *It is estimated by A. Emory Wishon, one of the leaders in the industry, that every time 25 horsepower in new installed capacity is placed in operation, three hundred acres of arid land formerly worth $3600 becomes productive land, valued at $28,000, and producing annually new crops valued at $12,000; or, in the cities, for another 25 horsepower started in the mountains or in the city steam electric plants, an average of a factory and a half, with a capitalization of $147,400, comes into being, with 100 horsepower in new motors installed, employing from thirty-three to thirty-four new employees and producing over $206,000 worth of new commodities.*

Furthermore, the labor, cement, and vast quantities of machinery involved in the building of those great hydroelectric plants has a "self-interest" appeal to every phase of industry.

This plan of selling stock to consumers soon spread beyond California, and today throughout America this method of finance is largely in vogue for securing the necessary financing of public utility enterprises. Probably as much as five to ten billion dollars of capital investments have been secured in this way. In California, one company alone, the Southern Cali-

fornia Edison Company, has sold its stock to over 124,000 consumers.

A social aspect of power development has grown up along with the evolution of the physical and financial aspects. The people of the commonwealth demanded, and rightfully, not only courteous service in the supply of electric power, but also that in the installation of electrical equipment in the home no workmanship be shoddy or poorly done. In the beginning of the rapid growth of the industry many young men who in their boyhood had wired front doorbells, or played with storage batteries, mistakenly considered themselves competent to do the more intricate installation of electrical equipment.

Experience soon led the public to demand that the electrical industry itself—the manufacturer, the jobber, the central station, and the contractor dealer—should assume the responsibility for guaranteed service in equipment and in installation. Leaders in the industry were called together to discuss how problems involving the public could be more satisfactorily solved and the industry purged of its shiftlessness and its inability to deliver the competent and efficient service which the public rightfully demanded. This resulted in the formation of the California Electrical Bureau, an organization to which central stations, jobbers, manufacturers, and contractor dealers contribute money in sufficient sums to enable them to employ experts to instruct consumers in the best ways for wiring electrical homes and the use of equipment.

It is interesting to note that the term "convenience outlet,"

now universally employed in America to designate the electrical outlet for connecting up all electrical appliances in the home, originated in California. It was through the efforts of the California Electrical Bureau that the "T" slot concealed contact receptacle became standard. Each manufacturer had originally turned out a different type of outlet, catalogued under a different name. The advantage of a standardized type and name soon became evident, and a member of the advisory board of the California Electrical Bureau went to Eastern wiring device manufacturers and succeeded in selling the idea which led to the present standardization throughout America.

Another step in raising the standard of electrical installations was the persuading of city electrical inspection departments to improve their electrical ordinances. In many cases it was found that these ordinances had been in existence and unchanged for fifteen or twenty years and had become obsolete, despite the strides which had been made in electrical development during that time.

Another advance is in the encouragement given to architects and builders to install more and more conveniently placed outlets for electrical uses in the home. Surveys showed that the average number of convenience outlets installed was one per home. After a little over two years of effort this average was increased to one and a half per room. One of the methods employed to encourage builders to meet these increased standards was an agreement entered into whereby on every home in which the builder installed at least one convenience outlet per

room the bureau would place a placard reading, "This Home Equipped With Electrical Convenience Outlets," thus advertising the house.

Arrangements were made with a number of builders throughout California to construct a home and wire it according to plans and specifications prepared by the bureau. The house was completely furnished and the public was invited to visit it. Although every kind of domestic electrical appliance was displayed, the selling effort was not directed so much toward the appliances as toward the wiring. The attention of visitors was called to the fact that the appliances could be used with a maximum of convenience and efficiency because of the position of the outlets. The display of these homes was continued for several years and they were visited by thousands of people.

With the installation of a greater number of convenience outlets in homes, the use of electrical appliances grew substantially. The industry, therefore, prepared a set of specifications designed to represent the minimum which could go into a home and still enable the occupant to use electricity satisfactorily. These specifications were called the "Red Seal Standards," and builders were given to understand that by specifying that their wiring conform to the "Red Seal Standards" they would be assured of an adequate installation, because the California Electrical Bureau would inspect the wiring and see that it conformed to the established standards which provide for all of the technical characteristics so often overlooked. The growth

of this plan has been amazingly rapid when all the added requirements are considered.

The "Red Seal Plan" has been extended recently to include commercial structures by the preparation of a set of specifications designed to provide installations which assure good illumination in stores, office buildings, hospitals, and hotels. Its reception by architects, engineers, and builders indicates that it fills an even greater need than was filled by the residential specifications.

All of which might seem at first sight to be far removed from the main purpose of our subject, an attempt to work in too great detail on a canvas admittedly "as wide as humanity." The fact is, however, that one day that whole canvas is destined to be filled in in just such detail. When this is realized, the limitless nature of the future and the immensity of the task is seen more clearly. One day there must be a "Red Seal Plan" in Leningrad just as surely as there is today in Los Angeles, in Omsk as in Oakland.

Let Us Do in Four Years What We Started to Do in Five

The ominous hand in the upper right-hand corner points to the building of vast power houses and dams for the Five-Year Plan, and below the slogan says: "Let us do in four years what we started to do in five."

PART III

The Answer

CHAPTER I

GERMANY ALMOST THE PERFECT MECHANISM

I HAVE PRESENTED the picture of "Electrified California" thus in detail, as set forth in Part II, in order the better to establish the goal before the world in general and Russia in particular. The world cannot refuse to accept the goal; it *has* to accept it. Germany and Russia present the two most interesting examples in the world today in differing methods of pressing forward to attain this goal.

No one can visit Germany and spend two or three weeks within its industrial confines, or mingle with its people, generally, but must become impressed with the fact that the German people, as a whole, are industrious almost to a fault; that they are conserving on all sides the agricultural possibilities of their land and putting every square foot of land to useful cultivation.

In their industrial efforts, one cannot but come to the conclusion that they are painstaking and accurate and are, indeed, masters in modern industrial research. Their accomplishments in engineering and invention, too, are most impressive. Their ocean-going vessels plying the Seven Seas testify to their masterful efforts in this regard. The Graf Zeppelin, a mighty pioneer in air travel, has carried the German message of inventiveness to far corners of the world. The great Ruth accumulators, conserving hundreds of thousands of kilowatt hours

of stored energy in the supply of Berlin and her municipal electric power uses, are another interesting world record that taught engineers of the World Power Conference of German mastery. The Benson boilers, likewise, observed in the Siemens–Walska works, utilizing hitherto unthought-of pressures of thirty-five hundred pounds, made boiler practice in other parts of the world seem juvenile by comparison. With electric power as a measuring stick, we have a new and accurate common denominator for all human effort in this machine age. On the basis of her electric power development, notably in Bavaria, in such power achievements as the Walchensee enterprise of 168,000 horsepower, Germany ranks well up among the nations of the world.

In political life, too, Germany has had a new awakening. Unquestionably, the former Kaiser and his false standards of government have long since passed from the German mind as usable or desirable. A large body of German citizens today has forsaken the ideal of war as a means for bringing about supremacy in world affairs. Hence they are basing their reliance almost solely upon the fruits to be gleaned from scientific research.

There seems, however, to be lacking in German enterprise that spark of enthusiasm which kindles initiative that has made American enterprise known throughout the world. Call it salesmanship, if you will, but beyond what you may call salesmanship is a spiritual spark, an ideal, that makes American accomplishments possible and outstanding in the world.

Within German industry there is lacking that *esprit de corps* which prevails in America between the worker and the man higher up. Said young Josef von Miller, son of Oskar von Miller, president of the World Power Conference, "In my year in America working with the General Electric Company I learned to admire the American spirit in industry." What he was alluding to, of course, is that personality of *leadership* which inspires a group of workers with loyalty and enthusiasm.

The German, with his highly scientific mind, places at the head of his big enterprises the scientific investigator, the doctor of engineering, perhaps the master of the science that has brought the industry to a state of perfection technically, an outstanding man in every sense of the word, but a man who too often proves lacking in those qualities of human understanding that have made the American industrial leaders so effective and the output of American industry pass into ever-increasing usage, not only in America itself but throughout the world.

America is blessed with gigantic natural resources, and their very presence seems to beckon to her citizens to go afield and study the economic process of a new world. But all these would be valueless if it were not for that "light of a new enthusiasm," so typically individual, so typically American, an enthusiasm which is never thwarted by the merely traditional way of doing things.

CHAPTER II

RUSSIA

Russia has seized upon the idea that by the economic utilization of her vast natural resources, the calling of her people from the fields of agriculture to industrialized efforts in the cities, she will—by this tying in with the machine age—secure prosperity and freedom from economic repression. Fearful of her unstable and unequal position she has built up a vast army. Somewhere between 500,000 and 1,000,000 men stand ready to prevent any attack on the infant régime, from without or *from within.*

She has rid herself—as far as the rulers are concerned—on a purely utilitarian basis—of everything that would stand in the way of "winning the war." Vodka has gone, and the loose woman has ceased to ply her trade openly. Russia advocates education—nation-wide education—as the best way to raise her citizens to the highest and fullest life. True, she has her own idea of what education should be, but she stands for education. At an opportune moment, the political party at present in power, aided by the widespread ignorance of the people and a line of rulers whose trail of activities for four hundred years had been one of blood-lust and cruelty, was able in one hour's time to establish itself in power with a security perhaps never before enjoyed by revolutionary forces.

And so with the stage thus quickly set, the Soviet rulers have embarked upon the gigantic task of rehabilitating a nation needing rehabilitation in practically every useful phase of civilized life.

The Soviet has instilled in her youth the "war spirit in peace time," and a certain vision and enthusiasm of accomplishment *for the Soviet régime.* The old cry of the chauvinist in its new dress is heard everywhere, "My country—my system—right or wrong." Everything—in theory, at least—is done to make the soldier "fit," compensating the workers and insuring them against old age and so on and on.

In her determination to abolish the superstitions of religion Russia has abolished religion altogether, and she has made a new religion out of the laws of science, inventive genius, and the survival of the fittest. She has established her Five-Year program of industrialization and boldly announces to the world that within five years Russia will be independent industrially and economically and ready to place upon the markets of the world industrialized products so cheap that the world itself must come to her doors or else turn Soviet in its struggle for a satisfying life. Whether this policy is right or wrong, she has given to her people nevertheless a vision of a common goal toward which all may work with a war-time sense of coöperation.

Nevertheless Russia is confronted with almost insuperable obstacles. For the moment her workers are buoyed up by a war-time hope, to amazing heights of self-sacrifice and self-

effacement. They talk of freedom, but what is their real position? They go where they are told to go; do what they are told to do; receive what the government chooses to give them; and work the number of hours the government determines. As Paxton Hibben has well put it: "Not only their bread and butter depend upon the Soviet government, but their future, their chance to prosper and to live comfortably. If they are not equal to their tasks they soon drop out. The progress is too swift for them. Naturally they all support the present régime, whether they be members of the Communist party or not, for the present régime represents their opportunity to succeed in life. Their loyalty is not the least political. It is the vital loyalty of those whose very existence is bound up with that of the present government of Russia."

And so, after all its wild excursion into the world of freedom, the great inarticulate mass of the Russian people is inarticulate once more. That which was in the beginning is once again, *now,* and, if the Soviet has its way, ever shall be. Autocracy is everywhere enthroned. The army of bureaucrats is larger than ever; the soldiery more dominating; the police more tyrannical; the four thousand more privileged and class-conscious; the 150 million more driven and downtrodden. If the czars came back to Russia tomorrow they would find their house in order.

"The more it changes, the more it is the same thing," so the old French proverb has it. No phrase could better sum up the story of Russia today, and at any time during the past twelve

years. She is still in bonds; bonds more unbreakable than ever before. In her immense military power and secret police system there lurk forces that history shows have, on many former tragic occasions, swept on to the devastating point with startling suddenness and destroyed all the things of good that lay in their path. Russia's semiofficial reports, which only allow to filter through such things as she wishes to feed to her people for mental consumption, are unquestionably sowing the seeds of discomfiture and distress that will cause her children some day to rise in protest, if not rebellion, with confidence utterly shattered in any statement that may be issued from the central authorities.

Russia suffers greatly from the inefficiency of her workers, the lack of proper food and clothing, and little or no funds wherewith to buy the necessary machinery and working tools for the carrying on of her Five-Year Plan. Then again, while Russia has made some progress toward the simplifying of her language, she suffers, nevertheless, from those same three drawbacks which all Europeans suffer from—lack of a common language, lack of common coinage, and lack of a standardized product. Perhaps these three factors alone, reversed in the United States, have had more to do with America's material progress than any other three in her present world supremacy.

But enough! To get down to cold fact, let us see what this Five-Year Plan of Soviet Russia proposes to accomplish electri-

cally, even if successful, and compare the "forces" thus marshaled with those of America.

The total generation of electrical energy in Russia during 1913 was 1925 millions of kilowatt hours. By 1928, at the beginning of the Five-Year Plan, this had risen to 5180 millions of kilowatt hours, and at the end of the five-year period it is estimated to be 26,000 millions of kilowatt hours. In America as far back as 1913 the total electrical energy generated was 14,000 millions of kilowatt hours; by 1928 this had risen to 77,000 millions; and at the same rate of increase during the last two years by 1933 it will rise to the huge total of 134,000 millions of kilowatt hours.

Hence, granting that the great Five-Year Plan is successful, Soviet Russia will be far, far from overtaking the American program.

Again, in the matter of size of units of power development, one hears on all sides in Russia that when the Dnieprostroy is completed Russia will have the largest single hydroelectric generating station in the world. While this is true, it is interesting to note that one single river in California—the San Joaquin—has upon it *already developed* a series of power plants totaling almost a million horsepower installed capacity. In other words, due to the swiftly falling rivers of California it is impracticable to develop the power efficiently in a single jump of the river. Several units are involved in the complete development, yet in total this project on the San Joaquin—a river less than one-tenth the volume of the Dnieper—exceeds the accomplish-

ments of the world-famous Dnieprostroy. And when other rivers of even this one American commonwealth are taken into account, the total power of district units and the per capita consumption of electricity outrank so far any accomplishment of the Five-Year Plan of Russia as to make Russia's great enterprise sink into insignificance in comparison.

Further than this, it is interesting to note that Doctor S. A. Koukel-Krajewsky, in his paper before the second World Power Conference on the Five-Year Plan of electrification in Soviet Russia, states that average cost of electric energy in Russian currency per kilowatt hour in 1933, when her vast economic program is to be completed, will be—at the consumer's end of the line—3.5 kopeks per kilowatt hour, or about 1.75 cents in American money. *This allows nothing for payment of taxes because the entire project is government owned.*

On the other hand, in a previous chapter, we have shown from reports of the California Railroad Commission that last year there was delivered to 49,067 different farms of California 956 millions of kilowatt hours at a cost of *only 1.41 cents per kilowatt hour even when state and federal taxes amounting to almost 10 per cent of the sale price had been paid by the companies.*

CHAPTER III

THE ANSWER TO THE CHALLENGE

Russia has obliterated the home, cast aside the religion of her fathers, and attempted to kill the individual, keeping only to the broad principles of collectivism and the development of the body politic in contradiction to the effort of home-building that America has always considered fundamental. While Russia, today, is a long way from handling the juvenile problem that stalks on every street in her great cities, and while a lack of international credit, insufficient food, and inefficient workers would seem to threaten her hopes of accomplishment, these, however, in themselves, are not the forces that will ultimately thwart her purpose.

Of the three outstanding and fundamental elements that have entered into America's success, Russia possesses only one to a helpful degree, namely, vast natural resources. America's world supremacy has been brought about, first, by the fact that she is a country of vast natural resources; second, that she has seized upon the scientific method of developing her industry to a degree never before accomplished in the history of the world; third, that she has put back of this industrial accomplishment a spiritual force, appealing to each individual citizen, which spurs him on to ever-increasing endeavor.

America has taken care of her workers. Dexter S. Kimball, past president of the American Society of Mechanical Engi-

neers and certainly one of America's foremost authorities on industrial matters, stated in his recent series of lectures before the graduate school of business administration at Stanford University (December, 1930) that America has become the most outstanding nation in the world industrially, financially, and politically because of her natural resources, the willingness of her cosmopolitan citizenry to work, and the willingness of her employing group to pay a just reward. This reward, he stated, consists not only of a money remuneration, but also of protection given to the worker while at work, and of living and cultural surroundings afforded him in his home life during his hours of recreation.

As to the part natural resources have played in American development, as compared with the latter two reasons for our outstanding achievements, he called to the attention of his hearers the fact that the same natural resources existed in America when the American Indian was in possession of the country, and no one ever heard of America's industrial prowess at that time. The reward given to the worker is not of the paternalistic type prevailing in Soviet Russia, but is direct, and encourages the worker to be self-reliant and to depend on his own planning and resources to bring about his comfort and protection.

And how has this been accomplished?

This has been accomplished by four fundamental traits deeply ingrained in the American life: First, a love for and devotion to an ideal of service on the part of those who have

been in power; second, an attitude of open frankness toward the public and toward fellow-workers; third, an instilling of ideals that at all times preserve the vital initiative in human endeavor; and, finally, the creating of an overwhelming public sentiment that each individual citizen, no matter how unimportant in worldly affairs he may appear to be, shall be given as far as reasonably possible an equal opportunity to further himself in life's accomplishments.

As an example of America's answer to the challenge of Soviet Russia, the electric industry is outstanding. In an industry now collecting from the people something like $150,000,000 in the state of California annually, and in America as a whole in excess of $2,000,000,000 annually, there has arisen a necessity for complete understanding between the public and the electrical industry. Undoubtedly, much of the success with which these great electrical enterprises in America have been attended is due to the confidence felt in the integrity of the industrial leaders by the American people as a whole. This has given opportunity for the play of personal initiative, and has made possible accomplishments which are inspiring.

The preservation of this spirit of initiative would seem essential. President Herbert Hoover, a splendid example of American idealism, possessed of statesmanlike engineering vision, has said, "The progress of our nation can come only by preserving on the one hand the vital initiative and enterprise of our people and on the other hand equal opportunity for all."

Bound up with this is, of course, first and last the idea of service. As Russell H. Ballard, President of the Southern California Edison Company, said recently: "Our grand objective, indeed our reason for being, is service. Let us continue our devotion to our objective. So long as we give the best that is in us toward providing the most efficient service at the lowest possible cost, we may safely leave to our public the decision as to the extent to which its interests are really being served."

In California, this spirit of initiative and enterprise and service has been allowed to express itself to the fullest. Upon its rate-fixing and regulatory body, known as the California Railroad Commission, have sat men of the highest principles. They have acted with such carefully discriminating judgment that the courts have in but few cases disagreed with their decisions. Quite typical of the high regard in which the founders of this body are held, is the expression on the part of the students of the University of California when, in summing up the life of the founder of the California Railroad Commission and its first president, the late John M. Eshleman, they carved upon his bust, installed on the campus of the university where Eshleman had graduated twenty years before: "Against the odds of poverty and constant ill-health he made his way, always serving his fellow men with ability, courage, and honesty."

Leaders of the electrical industry in California have, with their devotion to the highest business ideals, completed the social aspects of this picture in the commonwealth of California. Early in the life of this industry, these leaders realized that

Niagara

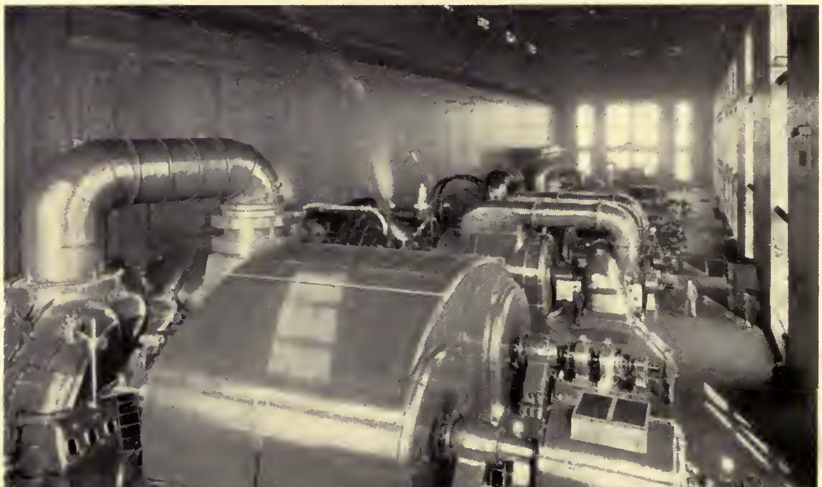
Although surpassed in volume and height by several other falls throughout the world, Niagara is still the world's great symbol of water power.

Niagara Falls From the American Shore

In spite of the intensive development of its water power below the falls, as shown in the smaller illustration, the singular beauty of Niagara has been in no way impaired.

The Jordan Dam Power House of the Alabama Power Company

This company "way down South" delivers some 2,000,000,000 kilowatt hours annually, "serving people of moderate means in city and countryside."



The Hell Gate Turbine Room of the New York Edison Company

This installation of 160,000 kilowatts capacity constitutes the largest single shaft turbine in the world.

aristocracy, an autocracy of brains, which in my belief eventually will destroy Communism as it now exists. They never will be able to curb individual initiative. As soon as they come to see that a man's earning capacity differs in proportion to what he knows, Communism will pass. It is passing now; they are digging their own graves."

This intellectual aristocracy of brains to which Mr. Campbell refers, true to the pronouncement of that Galilean teacher of nineteen hundred years ago whom the Soviets today would rule out as a mere myth, will go forth into all the Russias and preach the gospel, "Ye shall know the Truth and the Truth shall make you free."

Soviet Russia today, in her gropings toward the light, is appealing to America for aid more earnestly than any people in all history has appealed to another nation. Everywhere one goes in Soviet Russia, one finds America's engineering and industrial leadership under full sway—in the construction of her huge power plants, in the teaching of industrial methods in her cities, in the reclamation of vast lands by irrigation, or in the putting over of her gigantic agricultural program.

America is not merely a physical piece of topography on the earth's surface. America is a spiritual or mental ideal. America is a type of progressive thinking that urges in her every step in national unfoldment complete satisfaction of the individual with the dictates of what he conceives to be the highest right. This American individual initiative is an inborn craving which

seeks directed expression under truly spiritual forces as surely as the magnetic needle seeks the pole.

In this pressing forward, in leaving the old landmarks and rejoicing to see them disappear, America is well-described by Hugh A. Studdert Kennedy, brilliant author of "The Impatience of a Layman": "America is a great idea finding lodgment with adventurous souls everywhere, and marshaling itself chiefly among the peoples of the west; standing for freedom; impatient of any form of dominance; relapsing, collapsing from its high ideals; but forever scrambling back again and ever on to a higher level. Getting up and going out, from the little colonies of the Atlantic Coast; pressing toward the west; impatient of restraint; impatient of dominance; impatient of law, yet ever reënthroning law with ever more enlightened power. Making mistakes; flying off at tangents; following cranks; following quacks; going around and going about, yet always found at the point of right when the call comes."

If, then, I were asked what the outcome in Russia is to be, I would answer: Soviet Russia, in her intense craving for American industrial methods, in her insatiable ambition to measure up to and surpass America in her achievements, has appealed to the very best America has produced to guide her.

Hence, Soviet Russia will awaken some day, if she attains her goal, with a complete incorporation of American methods. The efficient use of the type of American leadership and working tools Soviet Russia is adopting calls for that peculiar American flair for adaptation that has made America what she is today

in the matter of industrial supremacy. This peculiar American flair involves not only the mastery of the principles of scientific management in mass assembling, standardized products, and the thousands of other mechanical details, but the full play of that type of individual initiative so forcefully demonstrated in all American efforts. This efficient use of the American working tool can take place only where this same American principle is invoked. Otherwise, the effort must fall far short of the mark of attainment.

If the ultimate and final awakening of Soviet Russia is ever brought about, she will find herself as a nation possibly still calling herself Soviet Russia, but to all intents and purposes American to the core in education, in ideals of home, and above all, in the burning desire to press forward under the undying urge of the highest type of individual initiative. Whether Russia can ever succeed in this way may be problematical; that she can succeed in no other way is certain.

Appendices

APPENDIX I

RUSSIA'S FIVE-YEAR PLAN—SOME DETAILS OF PROGRESS

[As presented by Doctor S. A. Koukel-Krajewsky at the World Power Conference, Berlin, June, 1930. The original text translated from the Russian.]

1. Scheme of Electrification in the U. S. S. R.

"The first plan of electrification in the Soviet Union was elaborated in 1920 and was sanctioned by the Government in 1921. It is usually referred to as the 'Goelro (Committee for the Electrification of the U.S.S.R.) Plan'; reports thereon were submitted to the World Power Conference in 1924.

"Strictly speaking, the scope of the Goelro Plan was wider than could have been derived from its title. As a matter of fact it was only a general plan for the development of the entire national economic system during a period of ten to fifteen years. Operations had to set in at a time when industry managed only a small percentage of its production compared to its prewar output, agriculture and transporting accommodations having been ruined by the long external and civil wars. The ultimate stage of this development toward the end of the period was planned to be about 85 per cent over the average of the prewar output. It was intended not only to confine the task to the mere restoration of what had suffered from the war, but also to carry out technical reconstruction on the power basis.

"After the Goelro Plan had been sanctioned, a new government institution—the State Planning Commission (Gosplan)—was created whose board was made up of persons who had contributed to the elaboration of the Goelro Plan. This commission superintends the planning of work in the U. S. S. R. up to the present time.

"The plans for the development of industry, electrification, transport, commerce, finance, etc., are worked out by respective People's Commissariats (industry being controlled by the Supreme Council of People's Economy). The plans for the development of the welfare of individual districts are worked out by either state or community institutions. The Gosplan combines all these plans into a general scheme for a uniform economic system for the country as a whole, issues directions as well as sets limits which, after being sanctioned by the Government, are distributed to the municipal institutions for practice.

"The aims of the Goelro Plan are actually approaching fulfillment while a new general plan has not yet been completed.

"In May, 1929, the Government accepted a bill carefully adjusted to aid the development of national economy over the period from 1928–29 to 1932–33.

"Below are given several fundamental aims of the Five-Year Plan, as provided for the last year of the period, together with the corresponding aims of the Goelro Plan as well as the data for 1913:

	1913	*Goelro Plan for 1931 to 1936 (worked out in 1920)*	*Five-Year Plan for 1932–33 (worked out in 1929)*
Smelting of cast iron in million tons................	4.6	8.3	10.0
Coal output in million tons	36.0	63.8	75.0
Capacity of regional electric stations in megawatts (1000 kw. hr.)	147.0	1750.0	3000.0
Total output of electric power by all stations in milliard kw. hr.)	2.0	.....	22.0

"Toward the autumn of 1929 it already became evident that in the Five-Year Plan the rate of national economic development possible under the Soviet system had been underestimated, one of the reasons for the rapid increase being the adoption of the continuous five-day week which makes it possible to fully utilize the available industrial and other equipment. The results attained in 1928–29 actually exceeded the respective projects.

"Eventually the Five-Year Plan was revised, increasing the fundamental indices.

"Accordingly, the electric power output for 1932–33 is estimated at 26 milliard kw. hr.

"In the following pages the indices of the electrification plan are refigured in accordance with the new conditions, wherefore some of them exceed the respective figures referred to by the author in his report 'Power Supply of the Industry of U. S. S. R., and Possible Developments Over Period 1925–26 to 1932–33' submitted to the World Power Conference Sectional Meeting held in Tokyo in November, 1929, which report comprised the description of the changes in the power balance of the industry in the U. S. S. R. under the influence of the technical reconstruction of the power supply system.

2. *Fundamentals and Methods of Planning Electrification*

"The chief object of the Goelro Plan consisted in supplying the requisite amount of power to the country, avoiding, as far as possible, transportation of fuel. Hence the tendency to utilize the local power resources as well as all sorts of combustible refuse.

"The next task of the plan was to provide the country with cheap electric energy, so as to promote the creation of electric-power-consuming industries of which prewar Russia was totally devoid.

"The authors of the Five-Year Plan were confronted with the same tasks.

"However, whereas the Goelro Plan was confined to the projecting of large regional stations in industrial districts, the new Five-Year Plan treats the same fundamental problem on a deeper and wider scale. The plan of electrification has

become, indeed, a plan of energy supply stipulating for the creation of unison in power resources in all industrial districts. At the same time supplying of heat is planned to industry and individuals.

"During the first years of Soviet power, the nationalization of industry and the adoption of the prospective-plan-system have, as a matter of fact, blurred out the distinction between utility and private use stations, and between regional stations and factory power generating plants. The latter are justified exclusively in the cases in which they furnish the inner power resources of the undertaking while the larger power plants distributing energy over their district pay exactly the same toll as the regional stations. Accordingly, a series of such large power plants supplying power to local circuits have been rated as regional stations in the operative plan for 1929–30 and will be classified in the same way in subsequent years.[1]

"The capacity generated by the electric power stations classified as regional stations, compared to the total energy generated by all the existing stations, characterizes the degree of centralization of power supply in the U. S. S. R.

"The municipal stations in the districts in which the system of unified power economy is practiced are also counted as regional stations, provided they are heat- and energy-generating stations feeding power into the common network.

"The principle of the utilization of local fuel resources is applied to all the power stations, also that principle according to which any supply station in the U. S. S. R., generating sufficiently cheap energy, is bound to provide all consumers located near enough to use this power to advantage.

"For this reason, the distinction between the main group (regional stations) and other stations, both in respect to the utilization of local fuel resources and in respect to the centralization of power supply, is purely quantitative: the former distribute energy on a wider scale.

"A separate report is devoted to the development of central heat- and power-generating plants in the U. S. S. R. which constitutes one of the aims of the unified power economy.

"In planning electrification, two methods are applied for the determination of the requisite values of the generation of energy supply and the capacity of stations for the year in question.

"The first method, which is the fundamental one, considers the contemplated development of industrial and other branches in this particular area on the one hand, and on the other, the power resources of this district. Summing up the electric power output and the capacity of stations respectively for all districts, we obtain the values of the fundamental indices for the entire Union of S. S. R.

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[1] This is the reason why the table of regional stations given in the appendix comprises a number of stations greatly exceeding that mentioned previously as provided by the Five-Year Plan.

"Another method is applied which, while checking the first one, at the same time determines the summarized fundamental indices for either the whole Union or some individual district. These methods can be applied after the plan has been in effect a year, with regard to the gross industry output, both for total and for individual branches of industry (at present the calculation is based on the prices of 1926–27). On the basis of statistical returns for previous year, coefficients are calculated which establish the relation between the gross industry output and the consumption of power in the main branches of industry. This affords the possibility of estimating in our statistics the consumption by industry of the electric energy plus the energy termed 'mechanical energy,' *i. e.,* the energy generated by prime movers geared directly to working machinery, without the intermediary of electric motors. The coefficients characterize the degree of electrification and are based on the projected technical reconstruction. Thus the electric energy required by industry is figured from the total amount of energy consumption.

"The consumption of electric power by industry, transportation, and individuals (the percentage of power consumption by industry, compared to the total energy consumption in the country, varying in general very little), is estimated by statistical data and by data obtained by the first, fundamental, method.

"Therefore the total energy consumed by the country is obtained on the basis of the projected value of gross industry output.

"Assuming a certain percentage of losses, the value of electric power to be generated is worked out of the value obtained for consumption.

"The value worked out in this way exceeds that obtained from the estimation of consumption.

"As a further stage of prospective planning, several variations are introduced for a certain year with regard to the possible extension of the construction of electric supply plants in individual regions. The problem as to which of these variations affords the best assistance for the establishment of new undertakings is discussed with the offices in charge of the development of individual branches of industry.

"After all the questions connected with the distribution of new undertakings are solved, it becomes possible to introduce greater precision in the theme of electrification.

"The working out of annual operative plans for construction and development of electric power stations is accompanied each year by the checking of the conformity of the electrification plan of the development of national economy as a whole, whereupon, if necessary, amendments are introduced.

"The five-year prospective plan is, therefore, not a rigid, unalterable scheme, but subject to change when ameliorations are proposed.

3. Indices of the Five-Year Plan of Electrification

"Notwithstanding the intense electrification conducted at present and described in another report by the same author—'Development of Electrical Construction and Supply of U. S. S. R. over period 1923–1929'—a number of industrial districts will not be supplied with electric power until the last two years of the five-year period.

"The continuous five-day week[1] is being introduced in all industrial concerns to utilize the available equipment to a fuller extent. For electric power stations such system greatly improves the curve of annual load since the holiday and pre-holiday descents are eliminated. However, this system prevents the overhaul of equipment, formerly done weekly. The increase of reserve machinery and spare parts therefore becomes an important factor.

"Another task consists in producing, in the last years of the five-year period, a higher quality electric power—much higher, indeed, than is the case nowadays. Within the five-year period it is contemplated to raise the coefficient of the industrial electrification from 50 per cent (in 1927) to 82 per cent (in 1932–33), *i. e.,* the ratio of the electric power consumed by industry to the sum of electric power and that generated by prime movers connected directly to machine tools.

"For the reasons pointed out, the extension of electric power supply in the country should exceed the rate of the development of industry rather quickly although the latter is already very high.

"The following table demonstrates the growth of electric power supply generated by certain groups of electric stations for the first and last years of the period, as compared with the corresponding data for 1913:

GENERATION OF ELECTRIC ENERGY IN MILL. KW. HR.

	1913	*1927–28*	*1932–33*
Regional stations	431	1,814	19,000
Other utilities	239[2]	578[2]	1,500[2]
Total utilities	670	2,392	20,500
Factory plants	1,255	2,788	5,500
Total	1,925	5,180	26,000
In per cent	100	267	1,335
	27	100	500

"Besides the gigantic increase in generation of electric power one can note the increasing share of the group of regional stations in electrical supply system of the country. In 1913 this share amounted to 22.1 per cent compared to the total

[1] The continuous industrial week means that a plant is run continuously and uniformly all the year round. The week is reduced to five days, four of which every individual worker spends at work, the fifth day is a holiday, but not uniform to all workers.

[2] Including railway supply stations.

energy output while in 1927–28 the corresponding value rose to 35 per cent and finally in 1932–33 will arrive at more than 73 per cent.

"The following table shows the approximate distribution of electric power supply among groups of consumers:

ELECTRIC POWER SUPPLY IN MILL. KW. HR.

Groups of Consumers	*1927–28*	*1932–33*	*Percentage Increasement*
Industry	3,410	18,200	543
Out of this amount electrochemistry and electrometallurgy	(280)	(3,500)	(1,250)
Population	765	1,150	418
Transport	125	500	400
Out of this amount electric traction	(20)	(250)	(1,250)
Total consumption	4,300	19,850	460
Losses and service requirements	880	4,150	474
Total	5,180	24,000	460

"The above table illustrates the extremely great increase of electric power supply consumed by electrochemistry and metallurgy, this being due to the construction of several hydroelectric stations (the largest of which is the Dnieper scheme) as well as a few large steam-generating plants which will utilize coal refuse in the neighborhood of mines; these factors will allow of creating new electrochemical and metallurgical works in the U. S. S. R.

"In 1932–33, simultaneously with the Dnieper hydroelectric scheme, a powerful group of plants working on cheap hydropower will be placed into service as well as another large group located near Toula, also the Bobrikov regional substation calculated to utilize the cheap Moscow brown coal.

"The creation of such combined groups of power plants may be considered a new feature brought into existence by the peculiarities of the U. S. S. R. economic system.

"The following table shows the amount of electricity needed to balance the requirements provided for 1933, compared to productions of 1913 and 1928. Compare this with the above tables:

CAPACITY OF ELECTRIC STATIONS IN MEGAWATTS

	October		
	1913	*1928*	*1933*
Regional stations	147	561	5,300
Other utilities	139[1]	388[1]	800[1]
Public utility stations, total	286	949	6,100
Factory plants	750	924	1,600
Total	1,036	1,873	7,700

[1] Including railway electric stations.

Appendix I

"The scope of electrification to be assumed according to the Five-Year Plan is illustrated by the aggregate capacity of regional stations now under construction (including extension of stations already in exploitation and the construction of entirely new schemes) as well as by the scheduled capacity of these plants when in exploitation, specified for each successive year of the period.

SUMMARIZED PROGRAM OF CONSTRUCTION OF REGIONAL ELECTRIC STATIONS IN MEGAWATTS
(in lump figures)

	1929–30	*1930–31*	*1931–32*	*1932–33*
In construction during the specified year............	2,800	4,150	5,600	6,600
Out of this number to be placed into service towards.. end of year	500	655	1,600	2,000

"In working out the above program it has been found necessary to accelerate the construction of some individual stations, so that the construction term allowed for steam regional stations should not exceed two years. Heretofore generating plants were being constructed at a slower rate.

"The length of high voltage circuits naturally increases as the power stations increase their capacity. This is illustrated by the following schedule:

LENGTH OF HIGH-VOLTAGE LINES IN EXPLOITATION IN KILOMETERS
(in terms of single-conductor lines)

Tension	*1927–28*	*1932–33*
220	....	950
115	1,104	7,000
20–66	1,861	8,000
Total	2,965	15,950

4. *Qualitative Indices of the Five-Year Plan of Electrification*

"The gigantic growth of the quantitative indices of electric power supply in the U. S. S. R. has reduced the value of prerevolutionary assets in the power field to a practical zero. This growth in itself is bound to produce a revolutionary effect upon the qualitative indices of the electric supply system.

"Moreover, inasmuch as we are endeavoring to utilize to the utmost all those existing achievements of world-power technique, the efficiency of which has been actually proved, and since we have created a system of unified power economy, we are justified in anticipating towards the end of the five-year period such radical changes in qualitative indices as are attained in other countries as a result of continuous efforts.

"We are in a position to overtake elder industrial countries which still carry the burden of somewhat out-of-date power installations.

"Electrification of the country increases, as has already been pointed out above, at the rate of approximately 50 per cent (in 1927–28) to 82 per cent (in 1932–33), although the air blowers for blast furnaces of powerful metallurgical works which we are beginning to construct will limit the increase of electrification during the five-year period.

"The power supply per worker, i. e., the ratio of the number of kilowatt hours consumed by industry to the number of permanently employed wage earners has increased since 1925–26 more than three times, as may be seen from the following table:

POWER SUPPLY PER WORKER

POWER CONSUMPTION PER WORKER PER YEAR

	1925–26	*Provided for 1932–33*
Total amount of power (mechanical plus electrical) in kw. hr.	2,320	7,600
Consumed on motive power in kw. hr.	2,200	6,000
Electric power in kw. hr.	1,105	6,250
Power of engines actuating working machinery in h.p.	1.57	3.6

"We have included in the above table the power (in h.p. per worker) of the engines actuating the working machinery since this value usually characterizes the consumption of power per worker. Under the conditions in our country, however, this value would not appear representative, since it depends on the utilization of indicated power. Now, these conditions, especially in connection with the adoption of the continuous industrial week, are different for the two years compared; likewise, they make it difficult to make U. S. S. R. data truly comparable with those of other countries. We, therefore, maintain that the rating of power supply per worker instead of being carried out in terms of engine capacity should be made in terms of useful engine work.

"In the above-mentioned report of the author, delivered at the Sectional Meeting of the World Power Conference in Tokyo in November, 1929, it was shown that the *thermal coefficient of fuel utilization* for industry as a whole was bound to increase in 1932–33 by 40 per cent against the respective figure of 1925. This indeed had been foreseen in the original version of the Five-Year Plan in which the electric energy output in 1932–33 was estimated to be 19.1 milliard kw. hr.

"But in the later amended version of the Five-Year Plan the electric power output for the same year is projected to be, as we have mentioned above, 26 milliard kw. hr. However, we have not yet at hand all the data required for the calculation of a complete balance of power for industrial purposes. In any case, the thermal coefficient of fuel utilization in the new plan is liable to be still higher than that provided for by the first version of the Five-Year Plan.

"The specific consumption of fuel per kilowatt hour generated from the bus bars of a station is bound to decline as shown in the following table:

Appendix I

AVERAGE CONSUMPTION OF FUEL IN KG. PER KW. HR. GENERATED ENERGY
(the calorific value of fuel is assumed to be equal to 7000 cal.)

	1913	*1927–28*	*1932–33*
Regional stations	1.15	0.84	0.65
Other utilities	1.50	1.27	1.11
All stations of public utility	1.28	0.93	0.71

"The utilization of local power resources in centralized system of electric power distribution (groups of regional stations) is shown by the following figures showing the distribution of the aggregate capacity of stations in regard to various sources of power:

	October			
	1928	%	*1933*	%
Hydro	73	13	891	16.3
Peat	139	24.8	1,204	22.72
Anthracite culm	20	3.56	747	14.1
Sub-Moscow brown coal	12	2.14	435	8.2
Ural brown coal	6	1.07	263	4.96
Noncommercial grades of Donetz Basin, Kousnetzk Basin, and local coals	68	12.1	572.5	10.8
Shales	0	0	48	0.9
Gases of blast furnaces and other refuse of metallurgical works	0	0	384	7.25
Paraffin mazout and refuse of petroleum works	104	18.53	259.5	4.9
Highly calorific fuel brought to the places of consumption from afar	139	24.8	496	9.87
Total	561	100	5,300	100

"The following table represents the coefficient showing to which extent the capacity of power stations has been actually utilized. It should be noted that in view of the high annual increment it has been found advisable to determine this factor by dividing the annual output of electric energy by the projected annual capacity.

	1913	*1927–28*	*1932–33*
Regional stations	2,430	3,400	4,670
Other utilities	1,510	1,600	2,000
Total utilities	1,860	2,675	4,260
Factory stations	1,670	3,220	3,550
Total	1,770	2,945	4,080

"It is worth mentioning that in 1927–28 the power reserve of regional stations was below normal, wherefore the plant use factor in this group of stations is excessive as compared with the degree of the centralization of electric supply attained in that year.

"The considerable increase of the plant use factor at the end of the five-year period may be accounted for, besides the increased centralization of electric supply, also by the influence of the 'continuous working week.'

"The growth of the qualitative indices of electric energy supply was naturally bound to result in a considerable reduction of energy self-cost. The following table shows the cost of energy at the station as well as that of several systems of electric supply transmitted to consumers. The average value for the regional stations of the whole Union is also given for the first and the last years of the five-year period. The data for 1927–28 is based on available statistical returns, while those for 1932–33 are carefully estimated, and are in some cases perhaps somewhat high.

AVERAGE COST OF ELECTRIC ENERGY IN RUSSIAN CURRENCY (KOPECKS) PER KW. HR.

	1927–28		*1932–33*	
District	*At station bus bars*	*At consumer's end*	*At station bus bars*	*At consumer's end*
Moscow	3.84	6.46	3.3	4.3
Leningrad	3.67	6.82	3.8	5.3
Ural	2.88	3.81	2.5	3.8
Donetz Basin	5.82	7.55	1.8	2.3
Dnieper scheme	...	...	1.0	1.2
Georgian S. S. R.	...	...	3.1	3.7
Average for the U. S. S. R.	3.46	5.82	2.6	3.5

"The above data proves that the cost of electric energy varies widely for different districts as it depends upon the available local power resources.

"The cost of electric energy is calculated for all stations at uniform standards with an extra charge of 6 per cent on capital invested. The costs of electric energy, together with data on the local energy supply, are of vital importance for the selection of sites for projected establishments.

DISTRIBUTION OF CAPACITY OF STATE REGIONAL STATIONS IN EXPLOITATION AND UNDER CONSTRUCTION AS ESTIMATED FOR SEPTEMBER 30, 1933

	District	*Capacity in MW* 1	2
I.	Moscow Industrial Region	1028	275
II.	Nishni Novgorod District	209.5	270
III.	Ivanovo Industrial District	454	100
IV.	Leningrad District	625.5	280
V.	Ural District	407	360
VI.	Central Black Earth District	72	48
VII.	North Caucasus District	373.5	299

VIII.	Middle Volga District	107	65
IX.	Low Volga District	136	124
X.	Western District	57	24
XI.	Siberia	192	224
XII.	Caucasus Auton. S. S. R.	88	70
	Total for R. S. F. S. R.	3749.5	2139
	Out of this number hydro stations	239.5	385
XIII.	Ukrainian S. S. R.	1056	490
XIV.	Transcaucasian S. F. S. R.	360.5	79
XV.	White Russian S. S. R.	64	43
XVI.	Uzbekian S. S. R.	70	90
	Total for U. S. S. R.	5300	2846
	Out of which number hydro stations	891	732

[1] Under exploitation.

[2] Under construction less stations whose construction is to begin in summer 1933.

APPENDIX II

AMERICA'S WORLD STATUS IN THE USE OF ELECTRIC POWER

If Soviet Russia's Five-Year Plan of Electrification is successful, by the fall of 1933 Russia will have an installed generating capacity of 2,846,000 kw. Assuming that the additional installation work under exploitation in 1933 is successfully completed, this total will be expanded to 5,300,000 kw.

One hears on all sides in Russia that such an accomplishment will challenge America. Let us examine the facts. America in this year, 1931, already has in operation 7,928,094 kw. in hydro and 23,046,220 kw. in steam generating capacity, or more than four times the Russian total. The challenge therefore cannot be taken seriously. To show how far, even granting all the hurdles are cleared, Soviet Russia would fail in entering America's class, it is interesting to compare her ambitious program with that which has not only been projected but actually accomplished in America.

Let us for the moment take only that portion of Western America comprising the eleven Western states with a population of but 11,500,000 people. Let us compare the accomplishment of Russia's 150,000,000 people under her Five-Year Plan. In this section of America this present year, 1931, a year supposed to be in deep financial depression, 494,000 kw. in new generating capacity will be added to her vast interconnected system. This will make a grand total installed capacity of 5,284,172 kw.—a total in excess of the Russian proposal.

When the new projects visualized in this section of Western America or those actually under exploitation counted as completed, the Russian program would shrink still further in importance, even when compared to this small industrial section of America. For instance, there is one project, that of the Boulder Canyon in Arizona, which calls for twelve 75,000 generators. This one project, with its 900,000 kw. of installed capacity, impounding 30,500,000 acre feet of water—almost two year's run-off of the Colorado river—involves the construction of a dam 550 feet high, a world record in achievement. Its stupendous proportions dwarf the Dnieprostroy in comparison. So taken for granted are such great programs in America, the public takes little note of their forward progress.

Expenditures in power programs for 1931 in these eleven Western states are budgeted at $135,624,531, with additional hydroelectric and steam installations for the year 1931 totaling 494,000 kw.

America as a whole during 1930, with its vast electric power generating equipment, delivered the huge total of 90,076,000 kilowatt hours, from which a gross revenue of $2,155,000,000 was derived.

Since this book has dealt in large measure with the electrification of Russia under the Five-Year Plan, we shall give further detailed data from *Electrical West,* covering electrical progress in eleven Western states of America during 1930:

"Additions to generating capacity in the Far West for the year totaled 532,300 kva., the largest increase in any one year in the history of the industry. Steam plants, with 276,500 kva., comprised more than half of the total and exceeded hydro for the second consecutive year. Generating capacity in the eleven Western states is now 4,835,456 kw., which is 15.2 per cent of the total for the nation. Hydro plants total 3,012,161 kw. and steam plants 1,777,511 kw., with national percentages of 38.0 and 7.7. During 1930 Western plants produced 3,425 kw. hr. per kilowatt of installed capacity, whereas the national figure was 2,821 kw. hr.

"Gross revenue for the year amounted to $268,320,000 as compared with $261,-160,000 for 1929. Rate reductions on almost all classes of business were put into effect in various sections of the territory, but these had little effect on the total gross. Such decreases as occurred in revenue from power sales were more than offset by increases in domestic revenue. Experience of the past year has done more than any one thing to prove the stability of domestic load and to justify the load-building activities of the power companies. Operating expenses, exclusive of interest, taxes, depreciation, and sinking fund requirements, decreased from $96,300,000 to $96,200,000 with a consequent decrease in operating ratio.

"With only 9.6 per cent of the population of the United States, the eleven Western states have 13 per cent of the total electrical consumers. During the year just closed the number of customers in this region increased 73,435, bringing the total to 3,211,407. The classification of customers includes 2,508,281 domestic, 478,080 commercial lighting and small power, and 225,046 wholesale power and miscellaneous. The Western percentage of wired homes is still considerably higher than the national figure of seventy.

"In customers, generating capacity, and output, California heads the list of Western states. With 1,864,529 customers of all classes, this state has 57.2 per cent of the total. It is exceeded only by New York, Pennsylvania, and Illinois in the order named. If California's growth continues it will reach third place within two years, as Illinois has only 1,872,478 consumers at the present time. New York exceeds California only in point of energy produced.

"In generation per customer, the Western states head all regions of the country with 5,160 kw. hr. The national figure is 3,721.

"The growth of the Pacific Coast region during the last decade has been astounding. Influx of population, industry, and capital was revealed by the last U. S. census, yet only relatively small proportions of the natural resources and potentialities have been developed. Every power need brought about by this growth has been anticipated by the electric light and power companies. Meeting the growth prophesied for the next ten years and at the same time providing

adequate power supply for the new applications and new markets for electricity that are developing should result in even greater records than the Western power companies have set up to the present."

The power companies of the eleven Western states will spend $135,624,531 for new facilities during 1931 as compared with $139,800,000 in 1930. Construction of distribution lines will require $56,506,000, hydroelectric plants $33,296,000, transmission lines $21,332,000, and steam electric plants $17,037,000. This is all exclusive of the $70,000,000 initial appropriations for the 900,000 kw. Boulder dam installation which, with its ultimate ramifications, will doubtless represent an expenditure of a half billion dollars.

PERCENTAGES OF CALIFORNIA HOMES EQUIPPED WITH SPECIFIC ELECTRICAL DEVICES.

	Average Home	*Especially Equipped Home*
Air heaters	29.0	75.0
Chafing dishes	4.0	6.2
Clothes washers	25.0	56.2
Cream whippers	...	12.5
Curling irons	46.0	54.0
Dishwashers	...	6.2
Fans	8.3	37.5
Grills	8.3	12.5
Hair driers	16.6	12.5
Heating pads	16.6	60.0
Hot plates	8.3	18.7
Ice cream freezers	...	6.2
Irons	100.0	100.0
Ironing machines	4.0	6.2
Percolators	66.6	78.0
Ranges	12.5	78.0
Refrigerators	8.3	84.0
Sewing machines	71.0	50.0
Soldering irons	8.3	12.5
Toasters	87.5	72.0
Utility motors	4.0	18.7
Vacuum cleaners	100.0	100.0
Ventilating fans	4.0	25.0
Vibrators	...	25.0
Waffle irons	58.3	81.2
Water heaters	...	43.2
Electric clocks	...	12.5
Cooker pots	8.3	12.5
Floor polishers	12.5	25.0
Electric radio sets	66.6	72.0
Battery chargers	37.5	37.5

YEARLY GROWTH IN ELECTRICAL USES ON CALIFORNIA FARMS

	1923	*1924*	*1925*	*1926*	*1927*	*1928*
Number of consumers	28,778	33,258	37,907	43,286	47,416	49,067
Total revenue (in millions of dollars)	8.3	9.9	10.8	12.4	11.9	14.3
Kws. connected load	352,706	405,011	465,711	518,841	553,074	591,538
Millions of kw.hr. consumed annually	485	666	709	842	754	956
Connected load per consumer, kws.	12.28	12.21	12.32	12.15	11.68	12.05
Annual consumption kw.hr., per consumer	16,891	20,562	19,199	19,236	15,913	19,480
Price per kw.hr.	1.71	1.47	1.49	1.48	1.59	1.41
Kilowatt hour per kw. connected load	1,383	1,657	1,536	1,603	1,350	1,616

ELECTRICAL USES ON FIFTY-ONE THOUSAND CALIFORNIA FARMS

	Number of items	*Horsepower connected load*
Motors (all sizes not including domestic)	63,225	....
Farms receiving central station services	51,000	....
Lighting consumers	49,800	....
Irrigation motors	39,600	656,000
Flatirons	34,800	....
Washing machines	18,000	....
Vacuum cleaners	17,800	....
Toasters	17,000	....
Domestic water supply motors	12,500	24,000
Curling irons	11,980	....
Ranges	11,300	....
Portable fans	10,000	....
Percolators	9,200	....
Space heaters	9,300	....
Farms using electricity for cooking	9,060	....
Water heaters (fixed type)	6,700	....
Waffle irons	6,420	....
Sewing machines	6,400	....
Incubators	5,700	....
Table grills	5,480	....
Heating pads	5,320	....
Battery chargers	5,130	....
Bell transformers	4,980	....
Brooders	4,400	....
Cream separators	1,570	430
Shop motors	1,400	2,960
Milking machines	1,370	2,750
Feed grinders	1,280	5,400
Refrigerators	1,090	1,940
Immersion heaters (portable type)	1,060	....
Ironing machines (mangles)	820	....
Dehydrator fans	600	7,800
Wood saws	400	1,400
Dish washing machines	170	....
Silo fillers	115	1,760

APPENDIX III

POWER RESOURCES OF THE WORLD

The first World Power Conference of 1924, meeting in London, undertook an inventory of the world's resources in power, and in 1929 issued a booklet entitled "Power Resources of the World."

In view of the fact that this present book, "America's Answer to the Russian Challenge," is largely based upon the utilization of power as a measuring stick for civilization, we append herewith a number of interesting tables compiled in this authoritative issue of the World Power Conference to set forth in general the world situation in power from the physical viewpoint.

Power, as we know it in the world's utilization today in industry, is mainly gathered from four sources: hard coal, brown coal, oil, and water power.

Coal and oil production is usually measured in tons, although at other times it is measured in calories, a unit of heat value. Again water power energy is measured in kilowatt hours. In order that we may see how the production of power measures up in different sections of the world, we append herewith Table No. 1, which shows first the world production of the four basic power producers as measured in tons, then in thousands of millions of calories, and finally, in millions of kilowatt hours:

TABLE I

POWER PRODUCTION OF THE WORLD, 1927

Basis	*Category*	*Europe*	*America*	*Asia*	*Oceania*	*Africa*	*World*
Coal	Hard coal	615.5	557.2	74.4	17.2	12.1	1,276.4
(Millions	Brown coal	33.6	1.0	...	...	...	34.6
of tons)	Oil	24.8	222.0	14.6	...	...	261.4
	Water power	35.0	42.0	6.5	.9	.4	84.8
	Total	708.9	822.2	95.5	18.1	12.5	1,657.2
Calories	Hard coal	3,693	3,343	446	103	73	7,658
(Thousands	Brown coal	201	6	...	...	...	207
of millions)	Oil	168	1,332	87	...	...	1,587
	Water power	210	252	39	5	2	508
	Total	4,272	4,933	572	108	75	9,960
Kilowatt	Hard coal	615,500	557,200	74,000	17,200	12,100	1,276,400
hours	Brown coal	33,600	1,000	...	...	...	34,600
(Millions	Oil	24,800	222,000	14,600	...	...	261,400
of units)	Water power	35,000	42,000	6,500	900	400	84,800
	Total	708,900	822,200	95,500	18,100	12,500	1,657,200

The imagination is undoubtedly awakened in reading the above figures to contemplate how long such vast power production can take place without ex-

hausting the resources of the world, in these four lines of endeavor. Of course water power should run on eternally, or at least without change throughout the immediate centuries ahead. The best estimate of water power resources of the world with population, area, and utilization are set forth in the following Table No. II:

TABLE II

WATER POWER RESOURCES OF THE WORLD, JANUARY, 1927

Continent	*Population*	*Area Km²*	*H. P. Utilized*	*H. P. Potential*	*H. P. Utilized per head of population*	*H. P. Potential per Km²*
Europe	526,753,804	29,013,341	13,248,650	52,594,000	0.0251	1.81
North America	144,868,419	21,698,170	16,837,750	65,600,000	0.116	3.02
South America	73,719,146	18,834,299	751,200	54,600,000	0.0101	2.89
Asia	802,136,213	32,243,018	1,860,850	69,200,000	0.00233	2.14
Africa	128,394,936	23,926,281	14,000	185,930,000	0.000109	7.77
Australasia	55,391,654	11,552,579	242,500	16,650,000	0.00436	1.44
Grand Total	1,731,264,172	137,267,688	32,954,950	444,574,000	0.0190	3.23

The oil resources of the world, as estimated by the United States Geological Survey, are given in the following table, the ratio of barrels being 7:1; that is, seven barrels in one ton:

TABLE III

OIL RESOURCES OF THE WORLD

Country	*Millions of barrels*	*Per cent of world production*	*Relation between U. S. resources and resources of other countries*
United States of America	7,000	16.26	100.00
Canada	995	2.31	14.21
Mexico	4,525	10.51	64.64
No. South America (including Peru)	5,730	12.31	81.86
So. South America (including Bolivia)	3,550	8.25	50.71
Algeria and Egypt	925	2.15	13.21
Persia and Mesopotamia	5,821	13.52	83.14
S. E. Russia, S. W. Siberia, and the Caucasus	5,830	13.54	83.29
No. Russia and Sachalin	925	2.15	13.21
Rumania, Galicia, and Western Europe	1,135	2.64	16.21
Japan and Formosa	1,235	2.87	17.64
China	1,375	3.19	19.64
India	995	2.31	14.21
East Indies	3,015	7.00	43.07
World	43,056	100.00	....

Appendix III

As to the coal reserves of the world, much thought has been given. Unestimated reserves are known in Mexico, Switzerland, Denmark, Iceland, Norway, Montenegro, Turkey, Siberia, Malay States, Siam, Asia Minor, Ecuador, Bolivia, Brazil, and on the antarctic continent. Brown coal is not included in the estimate, as found in Oceania, South America, and in the arctic regions. However, below we append, we believe, a statement of the coal reserves of the world that will, with reasonable accuracy, show the location of these vast reserves to quite an extended degree of approximation in the different continents of the world:

TABLE IV

COAL RESERVES OF THE WORLD
(in million metric tons)

	Class of Coal			
	Anthracite	*Bituminous*	*Sub-bituminous—brown coals and lignites*	*Totals*
North America	21,842	2,239,683	2,811,906	5,073,431
Europe	54,346	693,162	36,682	784,190
Asia	407,637	760,098	111,851	1,279,586
Oceania	659	133,481	36,270	170,410
Africa	11,662	45,123	1,054	57,839
South America	700	31,397	.....	32,097
Total	496,846	3,902,944	2,997,763	7,397,553

One naturally wonders whether there are not other untapped sources of energy that man will some day make use of, even to far greater utilization than the reserves of coal, oil, and water power. For instance, how about the wind, the tide, utilization of solar radiation, subatomic energy?

In 1922 Professor Svante Arrhenius, in a series of articles delivered at Danzig, discussed twelve different sources of energy, and stated that the following tabulation set forth the possible potential resources of the world's storehouses of energy along these lines:

TABLE V

WORLD POWER RESOURCES

	Billion calories
1. Solar radiation of heat during the year	$3 \times 10^{12} \times 10^{6}$
2. Solar radiation of heat to earth, including air jacket	1330×10^{6}
3. Solar radiation of heat to the surface of the earth	530×10^{6}
4. Evaporation of water in the oceans and air	340×10^{6}
5. Energy of the water in the clouds	2800×10^{6}
6. Energy of the flowing water	55,000
7. Energy realizable from rivers	4,000

8. Energy of the air currents	33×10^6
9. Energy stored up in plants	160,000
10. Energy of the coal consumed per annum	10,000
11. Total energy of fossil coal	44×10^6
12. Total energy of earth oil deposits	120,000

Only four of the sources mentioned here can be considered at all, in spite of the fact that several calculations have been made regarding the generation of energy from the heat of the sun and the sea at the equator. These four sources are power energy derived from rivers, from coal, from oil, and from the air. In time, it may be possible for tidal energy to be captured, and a number of experimental installations have already been carried out to this end, but the success of such a system depends on a favorable land configuration, with the possibility of exact coördination between the tides during all the year. In England, the Severn scheme has been debated for a number of years, and recently the possibility of developing a tidal power system on the coast of Essex was also investigated, while in France work has been going on on the coast of Brittany with the same end in view. The calculation of tidal energy is not, therefore, a simple matter of the rise and fall of the tides with calculation of the total energy available from such movements. It is rather an examination of suitable territorial conditions which will allow the tides to be harnessed, and in this direction little has been done.

At the World Power Conference in Berlin a most fascinating discussion of utilization of tidal power was presented by the delegate from Argentina. It seems that some 200,000 horsepower are available in Patagonia, a southern province of Argentina. Due to the fact that tides rise to the height of 175 feet, the configuration of the country seems unusually suitable for reservoirs, and this tidal development would seem to have much prominence.

As to the tapping of subatomic energy and the utilization of solar radiation, the reader will find an interesting discussion, conducted by Sir Arthur Eddington, in his paper presented before the second World Power Conference. This paper is reprinted in Appendix IV.

APPENDIX IV

SIR ARTHUR EDDINGTON ON SUBATOMIC ENERGY

[*Sir Arthur S. Eddington, one of the foremost astronomers of the world, who has given a life of distinguished service to this problem, presented to the delegates of the second World Power Conference in Berlin this summer, the summer of 1930, the following treatment of the subject, "Subatomic Energy," disclosing a source of energy so vast as to make man's present reservoir of energy in falling water, known sources of coal, gas, and oil appear as but a drop of water in the ocean of possibilities.*]

The World Power Conference in its technical sessions studies the discovery, the economical supply, and the utilization of our natural sources of energy. You have invited me to occupy one of the hours when you relax attention from these sterner problems of our civilization. Will you forgive me if I use my privilege rather cruelly? I am going to tantalize you with a vision of vast supplies of energy far surpassing the wildest desires of the engineer—resources so illimitable that the idea of fuel economy is not to be thought of. We need not travel far to find this land of El Dorado, this paradise of power; the energy of which I am speaking exists abundantly in everything that we see and handle. Only it is so securely locked away that, for all the good it can do us, it might as well be in the remotest star—unless we can find the key to the lock. The cupboard is locked, but we are irresistibly drawn to peep through the keyhole like boys who know where the jam is kept.

Einstein has shown us how to calculate the amount of energy stored away in matter—subatomic energy we call it. "There is enough energy in a drop of water to furnish 200 horsepower for a year. We build a great generating station of say 100,000 kilowatts capacity and surround it with wharves and sidings where load after load of fuel is brought to feed the monster. My vision is that some day these fuel arrangements will no longer be needed; instead of pampering the appetite of our engine with delicacies like coal or oil, we shall induce it to work on a plain diet of subatomic energy. If that day ever arrives, the barges, the trucks, the cranes will disappear, and the year's supply of fuel for the station will be carried in a teacup, namely 30 grams of water—or of anything else that is handy."

I have called it a vision, but to the astronomer it is a great deal more than the extravagant speculation of the theorist. We look up at the sky and our telescopes show a thousand million stars. Every one of these is a celestial furnace which apparently defies the law which limits our terrestrial undertakings, *viz.*, that if you do not continually replenish your furnace it will die out. Geological, physical, biological evidence assures us that the sun has warmed the earth for at least a thousand million years; but the calculation originally made by Helmholtz and

Kelvin is still incontrovertible, that the sun's heat cannot have been maintained for more than twenty million years unless it is being fed from some secret store of energy of a kind hitherto unknown. By all ordinary rules the sidereal universe, which we see blazing with light, should have long since been dead and cold. None of the sources of power which your conference is exploring could have kept it alive for more than a small fraction of the time that it has existed. It seems then quite plain that in the stars the "cup of water" method of maintenance is actually in operation, or at least that there is some partial adaptation of it. To the engineer this prolific kind of energy—subatomic energy—is a Utopian dream; to the physicist it is a pleasant speculation; but to the astronomer it is just a common well-recognized phenomenon which it is his business to investigate. We as astronomers have not merely to acknowledge its existence; we have to study observationally the laws of its release—to examine how the rate of liberation of subatomic energy in different stars varies with the temperature, the density, the age of the matter concerned. We can also study how the supply is regulated so that a star fed with heat in this way is not blown to pieces or thrown into violent oscillation. This has proved to be a very difficult and puzzling subject of study, and it may well be that our present views are wide of the truth. I do not at all wish to insist dogmatically on the results and arguments that I shall have to put before you in this lecture. But I do insist that the study of subatomic energy is something imposed on us in the ordinary course of astronomical research, without which we cannot form any useful conclusions as to the evolution and general functioning of the stars. Like many important lines of research it is still in a very untidy and unsatisfactory state.

I insist that it is a practical subject for the astronomer, but I do not suggest that for the engineer it can be more than a dream for idle moments. I can see no escape from the conclusion that subatomic energy is the main fuel that feeds the celestial furnaces of the stars; but I do not wish to raise any illusive hopes that astronomers may, like Prometheus, steal the fire of the gods and make it available to men. Emerson's exhortation "Hitch your wagon to a star" is not to be followed too literally in a World Power Conference.

Before jumping to the conclusion that the stars are utilizing subatomic energy, there is a preliminary point to settle. Is it not possible that a star may be picking up continually from outside the energy necessary to maintain its heat? Some have suggested that the sun is kept hot by meteors falling into it; others have suggested that there is some unknown subtle kind of radiation traversing space which the sun collects. In short the question is, "Does a star live on extraneous power like a windmill, or does it contain its energy stored inside it like an accumulator battery?" I think all theories which postulate an extraneous source may be set aside because they fail in one essential respect. They provide only for keeping the surface hot; they do not provide for renewing the intense temperature in the deep interior of the star. The temperature at the sun's surface is about 6000

degrees Celsius; the temperature at its center is calculated to be about 40 million degrees. Heat flows naturally down this temperature gradient from the center to the outside and then into outer space, where it runs to waste except in so far as a little of it falls on the earth and other planets, giving us the warm sunshine. Clearly to maintain this state of things, the source of energy must be at or near the center of the sun; you cannot maintain a temperature gradient by supplying heat at the bottom end. The enormous temperature in the interior is essential in order to keep the sun distended to its actual observed volume against the force of gravity which tends to compress it, and if this temperature dropped the sun would shrink. The meteor theory only provides for maintaining the surface temperature. To provide for keeping the interior of the stars at temperatures of the order 10 to 40 million degrees, we must look for a source existing in the deep interior. It appears, then, a star contains stored within it the fuel that has to last for the whole of its life.

Surveying the various kinds of energy in turn we soon convince ourselves that the ordinary kinds would be used up in twenty million years or so, and no one now believes that the sun (and consequently the earth) are as young as that would imply. There remains subatomic energy, that is to say energy of constitution of the atomic nuclei and electrons which form the material of the star. The total amount of this energy is easily calculated. Einstein showed that there is an equivalence of mass and energy so that 1 gram of mass represents 9.10^{20} ergs of energy. (The number 9.10^{20} is the square of the velocity of light in C.G.S. units.) We have only to convert the sun's mass 2.10^{33} grams into ergs by the same factor; the result $1.8.10^{54}$ ergs is the sun's whole stock of energy. We know by measurement the amount of energy which the sun squanders every year by radiating heat and light into space; at the present rate of consumption the stock will last just fifteen billion ($1.5.10^{13}$) years. Thus by passing from the ordinarily known sources of energy to subatomic energy we extend the possible life of the sun about a millionfold.

This does not mean that the sun will last for fifteen billion years and then go out; it is not quite so simple as that. The energy which we are now considering is energy of constitution of matter; and, of course, if you remove something essential to its constitution the matter can no longer exist; it, so to speak, comes unstuck. And so as the stock of energy disappears little by little, the matter of the sun also disappears little by little. Now there is a well-recognized relation between the brightness and the mass of a star; the smaller star radiates less light and heat, that is to say it squanders its stock of energy less quickly. So we must allow for the fact that the sun will become less spendthrift in its old age; and its life as a waning star may be prolonged much beyond fifteen billion years.

Similarly we can show that the sun cannot be more than five billion (5.10^{12}) years old. Large masses radiate very strongly; and however large a mass we start with, it will have radiated itself down to the present mass of the sun within

five billion years. I have never heard of anyone who wanted a longer past for the sun than that; but if anyone should propose a theory involving greater duration, I think astronomers would be justified in saying emphatically, "It cannot be done." It is in fact more likely that we shall have to be content with a past duration of the sun very much less than this maximum estimate.

The process of supply of energy which we have here assumed is a very drastic one, involving as it does the disappearance of matter into radiation. We can picture the destruction of matter in the following way. The ultimate units which constitute matter are protons and electrons, *i. e.,* unit charges of positive and negative electricity. It is common to picture them as opposite kinds of knots or twists in the ether. The very latest theory, tentatively proposed by Doctor Dirac, is that the electron is a charge excited into an orbit of energy above the normal level, while the proton is the vacant orbit—the hole that is left unoccupied. If the charge should drop back into the hole or the two opposite twists should run together and cancel, our proton and electron have vanished and that much matter has been destroyed. The idea is then that a proton and electron can run together and cancel one another; nothing is left but a splash in the ether representing the energy thereby set free. The splash spreads out as an electromagnetic wave, which is scattered and absorbed until it is converted into the ordinary heat of a star. The process is not difficult to imagine; but does it actually occur? Let me say at once that apart from doubtful and indirect inference from cosmical phenomena there is no observational evidence that it can occur. It is a conjecture. On the other hand I am not sure that it is more speculative to suppose that protons and electrons can end their existence in this way than to adopt the contrary view which supposes them to be immortal.

There is, however, a possible and less drastic alternative. It is possible for matter to liberate some of the energy of its constitution without going to the extreme measure of destroying electrons and protons. This alternative process is transmutation of the elements. By rearrangement of the ultimate units within the atomic nucleus a quite considerable amount of energy can be furnished. Radioactivity is an example of this. By transmutation of uranium into radium and of radium into lead a certain amount of energy is set free, the protons and electrons being rearranged but not destroyed. None of the known radioactive processes yields anything like enough energy for our purpose; and indeed it seems almost certain that a star is the place where the radioactive elements are synthesized, not where they break down. Ordinary radioactivity must be counted a source of loss rather than of gain to the star, because presumably the transmutation is there proceeding the opposite way from on earth and using up energy. The process which could provide stellar energy, as a possible alternative to annihilation of matter, is the building up of complex elements out of hydrogen.

A hydrogen atom consists of one proton and one electron. A helium atom consists of four protons and four electrons. They are packed in a peculiar way, four

protons and two of the electrons being cemented together to form a nucleus; but the essential fact is that the material of a helium atom is precisely the material of four hydrogen atoms. Although the material is the same the mass is not quite the same; the helium is lighter by about 1 part in 140. By Einstein's law of equivalence of mass and energy, this loss of mass is the measure of the energy that must be liberated if hydrogen is transmuted into helium. You see then that there are two possible ways of getting energy out of the four hydrogen atoms. They may disappear totally, each electron canceling a proton; in that case the whole mass is lost and the whole energy of constitution is set free to maintain the stellar furnace. Or they may arrange themselves so as to form a helium atom; in that case 1/140 of the mass is lost and 1/140 of the whole energy is set free. Slightly more energy is obtained if hydrogen is transmuted into a heavier element, *e. g.*, oxygen, instead of into helium, but the advantage is trivial. The energy released by transmutation of hydrogen is never more than 1/100 of that released by annihilation. So if we decide to accept the transmutation theory we must arrange to run the stellar furnaces on about 1/100 of the fuel provided by the other theory. That cuts down the time scale in the ratio 1/100, and brings down the maximum age of the sun to 100,000 million years. I dare say we can make that suffice.

I have been speaking of the formation of helium and other elements out of hydrogen as though it were an established fact. It is quite true that no one has ever succeeded in performing this transmutation; but that objection seems scarcely relevant. It is sufficient that we find in nature aggregations of protons and electrons in the particular formation which is called helium; and if we believe in evolution we must regard such a formation as brought about by the operation of regular physical laws and not as an act of special creation. The evolution of our ordinary atoms out of the primitive electric charges must have occurred at some time and place; and what place is more appropriate than the interior of a star, where the energy released by the process would serve the purpose of maintaining the star's heat. Can you suggest any more favorable place for Nature's workshop, where she forges a diversity of material of the primitive basis of positive and negative electricity? I have sometimes met with a critic who argues that the stars are not hot enough for this purpose; I am afraid that I so far forget myself as to tell the critic to go and find a hotter place.

We have then two possibilities, annihilation or transmutation; and I doubt whether at present we have the means of deciding between them. Probably it is best to keep them both in mind; and of course it is possible that both may be operating either simultaneously or at different stages of a star's life to maintain the output of heat and light. There is a general tendency nowadays to prefer annihilation; this is no doubt justified as a working hypothesis because it leads to much more interesting astronomical consequences which we can try to test, but whether it can claim to have satisfied the tests—whether it is the true hypothesis—is another question.

I will try to explain why it makes a big difference in astronomy which of the two sources of energy is in operation. Suppose first that we assume the second less drastic hypothesis of transmutation. Then only about 1 per cent of the total store of energy in the star is available to maintain its heat. Our peep through the keyhole shows us one hundred pots of jam on the shelves, but only one pot is fit for consumption. The star as soon as it begins to shine starts using up the store and losing the corresponding amount of mass. When it has radiated away 1 per cent, its supply is finished; the furnace must die out and the star become cold. The mass accordingly only changes by about 1 per cent during its whole history. On the other hand, if we assume the first hypothesis of annihilation of electrons and protons there is no such limitation. All the mass is now available to be turned into heat and radiated away. The dying out of the furnace is postponed and the star may live to radiate away 50 per cent, 75 per cent, 90 per cent of the mass it started with. In this second case, but only in the second case, we shall have an evolution of large heavy stars into lighter stars. That leads to the idea the difference between a massive star and a star of small mass is mainly a difference of age. As the brightness depends on the mass, this means also that the faint stars are evolved from bright stars. Many interesting astronomical developments arise out of tracing the sequence of this evolution. But all this falls to the ground if we confine ourselves to the transmutation theory; then there is no appreciable change of mass and we can only say that faint stars differ from bright stars because they were born different. So until we can decide between the two hypotheses we are like children speculating whether puppies grow into dogs or whether dogs and puppies have always been different.

It suggests itself that we should make an observational test whether big stars turn into little stars. It may not be an infallible test; but at all events it is a direct test. Let us take all the brand-new stars we can find and see what sort of mass they have. I think it is fair to assume that the most recently formed stars are those with very low density. We believe that the stars have condensed out of nebulous material, so the first stage should be a huge diffuse globe. Many such stars are known. A well-known example is the star Betelgeuse in Orion, big enough to contain the whole orbit of the earth inside it but so rarefied that its density is a thousand times less than that of the air in this room. Taking a list of about three hundred of the most diffuse stars and calculating their masses in a way which is believed to be safely applicable, we find that their mean mass is 3.6 times that of the sun and 9/10 of them are between 5½ and 2½ times the sun's mass. It appears therefore that the stars at birth seldom if ever have a mass so low as that of the sun. On the other hand, taking stars of all ages there are far more with masses below that of the sun than above it. It seems to follow that these must during the course of their lives have lost a great part of their original mass, having presumably radiated it away as the annihilation theory suggests.

Unfortunately there is other evidence of a less favorable kind. We sometimes find clusters of associated stars which have evidently had a common origin and therefore must have been formed about the same time. The Pleiades is an example. The theory requires that these coeval stars should be of nearly the same mass and brightness; because, although they may have had a considerable range of mass originally the range tends to lessen as time goes on; the large stars radiate away their mass very quickly and so tend to catch up on the small stars which radiate slowly. But this is not in accordance with observation; actually in the Pleiades the stars range over at least ten magnitudes. We have to admit exceptions to the theory that small stars are evolved out of big ones; this constitutes a grave blemish on the theory, and indeed makes us skeptical as to the whole idea.

In studying the stars as individuals there is, in spite of some difficulties, much that attracts us to the extreme time scale allowed by annihilation of electrons and protons—the view that the sun is somewhere about five billion years old. But when we turn to consider systems of stars, all the evidence indicates much less antiquity. It seems very unlikely that we can go back more than 10,000 million years—that is not so very much further back than geological time on our earth is supposed to extend. I am sorry to be so vacillating—in one argument putting the beginning of things as we know them billions of years ago and a few minutes later lopping three or four naughts off the age. But it all depends on which line of circumstantial evidence you trust; and the conflict explains why we are not able to be more explicit about the subatomic energy of the stars. Here is one of the chief arguments against any great antiquity of the stellar universe.

The ordinary stars numbering some thousands of millions form one great system, in shape very strongly flattened in the plane of the Milky Way. Toward the limits of this system the stars thin out in numbers, and around it there is vacancy. But we can look across this vacancy and discern other "island universes," great systems of stars of the same character as our own. There are vast numbers of them lying one beyond another as far as the telescope can penetrate. They are known as spiral nebulæ; in the nearer ones we can actually photograph some of the individual stars which, in spite of a distance which light takes a million years to travel, are not too faint for our largest telescopes.

Now the strange thing is that these other island systems are running away from us. Three or four of the nearest and brightest of them are rather undecided, not moving very fast either toward or away. But the others are determined. Quite unanimously, with very high speeds generally between 500 and 1500 kilometers per second, they are rushing away—as though our poor system were the plague spot of the universe. And moreover it seems that the further away the faster they go.

There is a very beautiful theory due to Professor de Sitter, based on Einstein's theory of gravitation, which explains why the island universes are scattering apart. But I do not think I need trouble you with the theory which is perhaps

rather speculative; the bare facts of astronomical observation are sufficient for my argument. If, as the observations show, the spiral nebulæ are running away and none are coming in to take their place, it is only a matter of time before they will all have disappeared into the distance. And this time is not so very long. The observed speeds and distances are such that in 1400 million years the spirals double their distance from us. Allow 10,000 million years, the distances will be seven times redoubled, and for the astronomers of that day the sky will have lost its most fascinating and beautiful features which we now contemplate in such profusion. Thus for a world enduring billions of years the spiral nebulæ can only be a very transitory feature of the sky. Strange that we should be here at the right moment to enjoy it! Again if we go backwards in time, we trace the position of these spirals nearer and nearer to us; we can scarcely place further back than 10,000 million years ago the event or development which started them off on this strange dispersal.

It is the same wherever we turn in regard to systems of stars. Whereas a star considered by itself is something which so far as we can tell might have existed with little change for untold ages, the vaster systems, the whole collection of spirals, our own galaxy of stars, the clusters of associated stars, are in much more of a hurry to get on with their evolution. They are not yet worn down by time to regularity, but bear the marks of comparatively recent origin. Comparatively recent, I may remind you, means in this connection something of the order of 10,000 million years, as contrasted with 10,000,000 million years, which is the alternative proposed.

Let us next consider whether astronomy has anything to say as to the conditions of release of subatomic energy. The answer appears to be quite definite yet one cannot help regarding it as incredible. The answer is that if you want to tap any really large supply of subatomic energy you must heat matter up to a temperature of 40 million degrees (Celsius). I will not guarantee that forty million is exactly the right figure. It may be thirty million or perhaps a little less; but my point is that there is a definite temperature somewhere about this magnitude at which matter seems to yield up its energy prolifically, whereas a few million degrees lower the yield is practically nil. It is almost like a boiling point.

The stars are now generally classified into three groups known as the giants, the main series, and the white dwarfs. The giants are comparatively few in number, and therefore presumably represent a rather transient phase of development. The white dwarfs are believed to be numerous, but owing to their low luminosity very few are actually known to us. By far the majority of the stars that we investigate belong to the main series. The main series comprises stars widely different in character, but they form one continuous sequence extending from the brightest to the faintest stars known; and if we admit evolution of faint stars from bright stars, we naturally take this sequence to be the regular track of evolution which every star follows for part of its life. It is found that from top to bottom of the

series the central temperature (which can be calculated by methods believed to be fairly trustworthy) remains practically steady at about 40 million degrees. At the top of the series we have very bright and massive stars radiating 10,000 times as fast as the sun. To keep up that output they must be supplied with subatomic energy at the rate of 1000 ergs per second per gram of material. Such a star must contract until by increasing temperature and density its material is stimulated to release subatomic energy at this rate. Near the middle of the series we have the sun which requires 2 ergs per gram per second to maintain its output; it must contract until the material attains sufficient temperature to release this amount. At the bottom of the main series we have stars requiring only 0.01 ergs per gram per second. But whether the amount required is 1000 ergs or 2 ergs or 0.01 ergs per gram per second, it appears that the central temperature has had to rise to 40 million degrees in order to give it. Judging from the fact that nearly all the stars have reached this temperature, we conclude that that must be the temperature at which the balance is attained. The obvious inference is that this is some kind of critical temperature at which the liberation of subatomic energy increases very rapidly.

Is this the key to the cupboard? Suppose we could manage to heat terrestrial matter up to 40 million degrees, could we extract its energy of constitution? I may remark in passing that, if this is the method required, the chances of our making a commercial success of it do not appear very promising; we should waste a lot of power in maintaining the matter at 40 million degrees while the stream of subatomic energy dribbles out of it. But I scarcely think it can be the key. It may have some bearing on the problem; but a more general survey of the difficulties than I can give here convinces me that there is a great deal more that we shall have to understand before we can put these astronomical results into their right perspective. I have given this result rather as an illustration of how a way is opening for research into the problem of subatomic energy through the properties of the stars; I do not wish to stress the first crude conclusions that have suggested themselves. Forty million degrees is perhaps not beyond attainment in our laboratories. At the Cavendish Laboratory Doctor Kapitza produces momentary magnetic fields in which the concentration of energy corresponds to about 1,000,000 degrees (Celsius). If he should be able to raise this to 40 million degrees—well, I have said that I do not really think that the subatomic energy will then come pouring out; but, just to be on the safe side, I shall take care not to be too near the laboratory when the experiment is first tried.

There is another condition of release which is of great importance in astronomy. It is necessary that the liberation of subatomic energy should be stimulated by increase of temperature; otherwise it will not automatically adjust itself to keep the star steady for long periods of time. But it must not increase too fast with temperature because that would have the effect of throwing the star into pulsation. We know of some stars which do pulsate, alternately swelling out and

subsiding in a period of a few days; they form a class of variable stars called Cepheid variables. Our present idea of subatomic energy would lead us to expect this behavior. At one phase of the pulsation the star's material is compressed and hotter than the average; at the opposite phase it is expanded and cooled. Its supply of subatomic energy will be stimulated by the increased temperature at compression and reduced by the lower temperature at expansion. The engineer knows well that this is just the way in which the heat supply of an engine must be regulated in order that it may be set working; heat must be supplied at compression and cut off at expansion. Thus the star becomes a kind of automatic engine which can maintain its own pulsations, or even start up a large pulsation out of a very small initial disturbance. The puzzle therefore is not to explain the Cepheid variables, but to explain why they are the exception and not the rule.

The pulsation will be attended by a certain amount of wastage; and the occurrence of pulsation depends on whether the engine effect that I have described is strong enough to make good the wastage. If the resistance is too great the engine will not start up. We must suppose that in the ordinary steady stars like the sun the engine is not strong enough to keep a pulsation going. That is one of the conditions that we have to attend to in considering any proposed law of release of subatomic energy. It is very difficult to find a law of release (a law stating how the liberation of energy depends on the density and temperature of the material) which will steer the star safely between the Scylla of instability and the Charybdis of pulsation. The passage is so narrow that it seems unlikely that any practical method of release of energy would operate so as to come between the required limits. I think that the only likely way out of this difficulty is the hypothesis that the stimulating effect of an increase of temperature is delayed. If the temperature is increased there is no immediate increase in the production of energy, but an active kind of material is produced which in due course (after weeks or perhaps years) disintegrates and liberates subatomic energy.

I now turn to an entirely different kind of phenomenon which may possibly be connected with the release of subatomic energy. It has been known for many years that there is in our atmosphere an exceedingly penetrating kind of radiation which can pass through great thicknesses of metal sufficient to shield off any ordinary X-rays or Y-rays. This phenomenon began to attain cosmical importance when it was discovered by W. Kohlhorster that the penetrating radiation flows downwards through our atmosphere as though it is coming into it from outside. Later work by R. A. Millikan appears to confirm its extraterrestrial origin and has added greatly to our knowledge of its composition and penetrating power. Kohlhorster's observations indicated that the penetrating radiation is strongest when the Milky Way is overhead. Our stellar system is strongly flattened in the plane of the Milky Way so that if the origin is in the stellar system we should expect this kind of relation to show itself—an increase in the intensity when the direction of greatest extension of the system is in the

vertical. Millikan, however, denies this correlation, and finds the intensity to be the same at all sidereal hours. This contradiction makes it very difficult to judge whether the phenomenon belongs to stellar regions or not; it was largely on the faith of the supposed connection with the Milky Way that astronomers first accepted this radiation as coming within their province. However, I will here assume tentatively that it really does originate in stellar regions.

The extreme penetrating power is taken as evidence that the radiation must be produced by a subatomic process. The familiar subatomic process of radioactivity—transmutation of the radioactive elements—furnishes Y-rays, which, next to rays that we are now considering, are the most penetrating known. Their still greater penetrating power presumably indicates that they are the result of an atomic adjustment or collapse still more energetic and drastic, such as we have imagined as occurring in the interior of the stars. Indeed it seems almost impossible to secure such highly concentrated energy in any other way. Theoretically if an electron were allowed to get up speed under the action of a very strong electric field and were then suddenly stopped it would emit radiation of this quality, but it is difficult to turn this into a serious working hypothesis. I might mention that the electric and magnetic fields in the stars and nebulæ are disappointingly weak compared with those which we can produce on earth; in the celestial power houses the energy is plentiful enough but the insulation is extremely bad.

It ought to be possible by measuring the penetrating power of the radiation—the thickness of lead or of water that it can traverse before falling to half strength—to infer the particular subatomic process that produces it. We have been considering two such processes, the formation of a helium atom out of four hydrogen atoms and the complete destruction of a hydrogen atom by cancellation of its proton and electron. Although we have never observed either process we can calculate quite easily the nature of the ray that would be emitted in each case. The second is thirty times as energetic as the first and would have correspondingly greater penetrating power. The result of the calculation is interesting; the observed penetrating power indicates the second process—the one which we have hitherto regarded as the more conjectural. I dare say that both observations and theory require more scrutiny before we can accept this as definitive. However, we will provisionally suppose that it is right. If so our dream has come true to the fullest extent. Out in the depths of space atoms are divesting themselves to the last shreds of their energy of constitution and passing out of existence. The last moan of the suicide (a very penetrating moan!) passes into the ether. In all directions through space are passing the rays proceeding from countless self-slaughtered atoms. In quantity the penetrating radiation is not much less than the visible starlight which is also traveling in all directions through space. When these rays strike the earth they pass down through our atmosphere, pass through roofs and ceilings, enter physical laboratories where they create insula-

tion leaks—to the annoyance of physicists occupied with other matters who are quite unable to keep them out. And this revelation of what is going on in the astronomical universe has come, not by looking through a big telescope, but because it was noticed that gold-leaf electroscopes were never perfectly free from leak however carefully they were shielded from all familiar sources of ionization.

Although the process which originates the penetrating radiation may well be the same as that which we have suggested as the source of energy of the stars, the one is not direct evidence of the other. Whatever is going on in the deep interior of the stars is shut off from outside contact. Penetrating is a relative term, and even the Kohlhorster–Millikan rays cannot pass through any considerable part of the thickness of a star. If protons and electrons are destroying one another in the hot central part of the star, the radiation generated will be absorbed in the interior and transformed down, until its turn comes to be emitted as part of the ordinary heat and light which leaks from a hot body. The penetrating radiation which reaches us directly must start, possibly from the cool outer atmospheres of stars, but more probably from the thin gaseous nebulæ and the general cosmic gas thinly scattered through interstellar space. That puts the problem of release of subatomic energy in a new light. Just now we thought we had found the key; the thing to do was to heat up matter to 40 million degrees, at which temperature it seemed likely that subatomic energy would issue forth in abundance. Now it appears that it is also given off in the diffuse clouds of interstellar matter which, even if it is not (as used to be supposed) at a temperature below that of liquid hydrogen, has certainly no very remarkable degree of heat.

We have a difficult riddle to unravel. It is not that there is a lack of clues to exercise our detective faculties on. There is a superabundance of clues, and unfortunately they all seem to lead in different directions. It is not the kind of problem to bring before the general public to illustrate the progress that science, and astronomy in particular, has made in conquering the unknown. It is rather a glimpse of the fog-bound frontier of knowledge where we are waiting expectantly a ray of light to dispel the obscurity.

The possibility, or perhaps the probability, that the matter of the universe is slowly dissolving into radiation raises the question whether there is any counter process. May not the radiation traversing the world somehow recollect and form itself anew into protons and electrons? On this point you may guess what you will; I have no light to throw. But do not forget that, although we might provide in this way for the renewing of the matter that has dissolved away, and for the renewing of the stars that have died out, there is an inexorable running down of the universe as the energy is degraded from an organized to a more disorganized form. Subatomic energy may extend the life of the universe from millions to billions of years; other possibilities of rejuvenation may extend it from billions to trillions. But unless we can circumvent the second law of thermodynamics —which is as much as to say unless we can make time run backwards—the universe must ultimately reach a state of uniform changelessness.

APPENDIX V

EINSTEIN'S METAPHYSICAL PRONOUNCEMENTS AT THE SECOND WORLD POWER CONFERENCE

(Translated from the German)

[Of the many colorful figures at the second World Power Conference none was more interesting than Professor Albert Einstein, famous for his theory on relativity. Those of us who had the pleasure of meeting him personally recognized in him not only a mathematician of great mental capacity but a human being of delightful and fascinating personality, of quiet, retiring nature, and of a spiritual facial expression strangely aloof.

Reference is made in the main body of this book to the apparent trend toward world unity of thought and action observable at the conference and in the several countries visited by the author subsequent to the conference. Professor Einstein was called in to tell the delegates concerning the trend of space, field, and ether problems in physics. And here, too, we found a unification that would bring into one mathematical expression the laws of gravitation and electromagnetic phenomena.

In the paper by Professor Einstein which follows we have tried to keep the English translation as nearly literal as possible so that the reader may acquire directly without personal interpolation Einstein's metaphysical or conceptional reasoning.

In his article Einstein deals first with the most elemental relationships of material bodies and finally shows, through metaphysical hypotheses in the choice of coördinates, how a common expression can be set up to represent the known empirical laws of gravitation and electricity. The translation follows.]

SPACE—FIELD AND ETHER PROBLEMS IN PHYSICS

Conceptions and conceptional systems, logically regarded, never originate from sense experiences. But they are always caused, however indirectly, by sense experiences; they are related to sense experiences, and in this relationship lies their meaning and their significance.

If we wish to be clear on the meaning of the prescientific conception of space, we must seek to visualize those characteristics of our world of experience which have given rise to the formation of a conception of space and of geometric conceptions in general. Regarded from this standpoint, the conception of a real world of externals and material bodies undoubtedly preceded the conception of space. And we need not further analyze what characteristics of the world of experience have led to these fundamental conceptions and in what the close linking-up of these concepts with the world of experience consists.

Among the many things which are included in the term "material objects" one category plays a particular rôle. This we call "relative position of solid bodies." The conceptions of space as well as the conception system of Euclidean geometry are based upon this idea. The most important conceptual element for the comprehension of the law of "position" of motionless bodies is that of their contacts. On this are based the most important concepts of congruence and of measurement.

The great significance of the geometry of the Greeks lies in the fact that, so far as we know, it represents the first attempt to comprehend a complex of sense experiences through a logical deductive system. Instead of starting from matter with its manifold forms, it is based on a few formal elements—point, line, plane, and distance. From these are constructed material forms and *positional* relations between bodies, which are purely theoretical and are founded on certain established rules, the axioms. These fundamental elements are themselves idealizations of material objects.

The conception of space continuum does not appear at all in Greek geometry, although this certainly forms a part of prescientific thought. It was first introduced into mathematics by Descartes, the founder of modern geometry. The Greeks were satisfied to study the reciprocal relationships between their idealized material objects—point, line, plane, and distance.

The conception of space is based on the idea that it is easier to study the relationships of all bodies compared to one, instead of compared to one another. This one body is, however, the fiction of an infinitely extended body or one with which all others can be brought into contact. It is clear that the existence of a quasi-rigid earth surface, *or* the existence of drawing paper in the study of plane figures, must have given rise, by means of the drawn representation, to the formation of this conception.

The service which Descartes rendered mathematics through the introduction of a space continuum cannot be too highly estimated. In the first place, this step made possible the study of geometrical figures by means of analysis. Secondly, it strengthened geometry as a science in a decisive manner. For, from now on, the straight line and the plane were no longer favored in principle over other lines and surfaces, but all lines and surfaces received equal treatment. A single axiom took the place of the complicated axiom system of Euclidean geometry. This axiom, in today's language, reads: There are systems of coördinates, compared with which the interval ds of neighboring points P and G may be expressed by the coördinate differentials dx_1, dx_2, dx_3, in the formula:

$$ds^2 = dx_1{}^2 + dx_2{}^2 + d_3{}^2.$$

From this, *i. e.,* from Euclidean metric, all conceptions and propositions of Euclidean geometry can be deduced.

However, perhaps the most important thing is that, without the introduction of a continuum of space in Descartes' sense, a formulation of Newton's me-

chanics would have been impossible. The fundamental conception of acceleration used in this theory must be supported by the conception of Descartesian coördinate space; for acceleration in nowise may be deduced from concepts which only relate to the relative position of bodies or material points and their time changes. It may rightly be said that, according to Newton's theory, space plays a rôle of physical reality, as Newton well knew, although this fact was later overlooked.

The Cartesian coördinate space had therefore, to begin with, from the point of view of physics, two independent functions. It established, through the Pythagorean theorem, the possible positions of practically rigid bodies as well as the inertial movement of material points. It seemed absolute in the sense that it worked, but that nothing could act upon it to modify it. It was the infinite, the eternally unchanging repository of all that is and happens.

The frame of the Newtonian theory is distinguished by the concepts of space, time, and imponderable matter. To this there came in the nineteenth century a new element, the ether. As soon as the undulatory character of light had been established by Young and Fresnel, it was considered necessary to accept an inert substance which permeates all bodies and completely fills all space—ether, whose vibrations were supposed to be light.

Newton's theoretical frame was completely destroyed by the Faraday–Maxwell field theory of electromagnetic phenomena. For the realization gradually grew that electromagnetic fields, which are also to be found in empty space, could not be regarded in a satisfactory manner as mechanical conditions of the ether without encountering objections. One got accustomed to regarding the electromagnetic fields as fundamentals of nonmechanical nature. Moreover, they were still regarded, as heretofore, as conditions of the ether which, however, could no longer be regarded as a form analogous to solid matter, all the less since, at the turn of the century, the conviction of the molecular structure of matter gained even more ground.

Even though these electromagnetic fields had established themselves as not mechanically graspable fundamental substances, there still remained the question of the mechanical characteristics of their medium, the ether. H. A. Lorentz answered this by stating: All electromagnetic facts force us to the conclusion that the ether is everywhere motionless, as opposed to Descartesian and Newtonian space. How close was the thought: The fields are conditions of space; space and ether are one and the same! That it was not realized lay in the fact that space, as the basis of Euclidean metric and of Galileo–Newtonian inertia, was considered absolute, *i. e.,* uninfluenceable. It was considered a rigid frame of the world which, so to speak, existed before all physics and could not be the basis of changing conditions.

The next step in the development of the conception of space was that of the special relativity theory. The law of the spreading of light in empty space in

connection with the relativity principle regarding uniform movement resulted in the necessity that space and time must be united in a single four-dimensional continuum. For it was recognized that reality did not conform with the conception of simultaneous events. A Euclidean metric had to be ascribed, as Minkowski was the first to clearly recognize, to this four-dimensional space, which, by the use of an imaginary time coördinate, would be completely analogous to the metric of the three-dimensional space of Euclidean geometry. On the existence of a space structure expressible through a Euclidean metric was founded the later development, the steps of which have become known under the terms "general relativity theory" and "unified field theory."

After it was realized that no absolute character could be ascribed not only to speed, but to acceleration, it was revealed that reality did not conform to the conception of an inertial system in nature. It was clear that the laws must be so formulated that this formulation could demand validity in four-dimensional space in terms of every Gaussian coördinate system—general covariance of equations which express the laws of nature. This is the formal content of the general relativity principle. Its force lies in the question: What are the simplest general equation systems of covariance?

This question in this generalization has not yet been productive. A statement has still to come on the character of the structure of space. This is supplied by the special relativity theory, the validity of which for infinite small areas of space must be granted. That means: there is a structure of space which for the infinitesimal surroundings of every point can be expressed mathematically through a Euclidean metric. Or: space possesses a Riemannian metric. On physical grounds it was clear that this Riemannian metric also formed simultaneously the mathematical expression of the gravitational field.

The mathematical question corresponding to the gravitation problem was therefore this: What are the simplest mathematical conditions to which a Riemannian metric in four-dimensional space can be reduced? In that manner the field equations of gravitation of the general relativity theory were found, which have received the well-known confirmations.

The significance of this theory for the recognition of the structure of space can thus be characterized: Space under the general relativity theory loses its absolute character. Until that phase of development, space was accepted as something whose inner substance was not influenceable and in no way changeable. Therefore a special ether had to be accepted as a basis of the field conditions localized in empty space. Now, however, the real quality of space, the metric structure, was recognized as changeable and influenceable. The condition of space gained a field character; space had become analogous in its structure to the electromagnetic field. The separation of the concepts of space and ether were thus, to a certain extent, automatically removed after the special relativity theory had already taken the last bit of substance from the ether.

Appendix V

The general relativity theory in its former shape would have been, from a logical standpoint, the ideal physical theory on account of its completeness, if there were only gravitational fields and not electromagnetic fields in nature. The latter, however, could not be represented through the Riemannian metric. One had to seek a structure of greater richness of form which would encompass the Riemannian metric structure and at the same time be able to mathematically describe the electromagnetic field. This task is to be solved through the unified field theory by the establishment of a space structure whose mathematical characteristic is as follows:

P and P′ are any two points of a continuum. $\overline{PG}$ and $\overline{P'G'}$ are two line elements going out from these points. The hypothesis of the metric structure states that the equality of the two line elements may be spoken of intelligently; more generally, that line elements are comparable in respect to their size. The Riemannian character of the metric is expressed by the hypothesis that the square of the size of the line element may be expressed by a homogeneous function of the second degree of coördinate-differential. On the other hand, a statement within the frame of Riemannian geometry about a direction relation, for example about parallelism of two line elements $\overline{PG}$ and $\overline{P'G'}$ has no meaning. If the hypothesis is added that parallel relations of the line elements can be intelligently spoken of, then one attains to a formal basis of the unified field theory. To attain completeness, it is now only necessary to add the hypothesis that the angle between two line elements going out from the same point is not changed through a parallel movement of the elements.

The mathematic expression of the field law should be the simplest mathematical conditions to which such a space structure can be reduced. The discovery of these laws appears to have been made, and they correspond in fact with the known empirical laws of gravitation and electricity in the first degree. Whether these laws also supply a useful theory for particles of matter and their movements must be shown by further mathematical investigations.

Taken together, we can say symbolically: Space, brought to light by the material object and raised to a scientific reality by Newton, in the last few decades, has swallowed up ether and time and is about to swallow up the field and the corpuscular theory as well, so that it will remain as the only theory representing reality.

GENERAL INDEX

COMPOSITION BY WILLIAMS PRINTING COMPANY,
SAN FRANCISCO, CALIFORNIA
PRESSWORK AND BINDING BY THE PLIMPTON PRESS,
NORWOOD, MASSACHUSETTS
PAPER FOR TEXT AND ILLUSTRATIONS FURNISHED
BY S. D. WARREN COMPANY,
BOSTON, MASSACHUSETTS